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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF FISHERIES

**PROGRESS IN
BIOLOGICAL INQUIRIES
1939**

By **ELMER HIGGINS**

ADMINISTRATIVE REPORT No. 39



UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, Secretary
BUREAU OF FISHERIES
CHARLES E. JACKSON, Acting Commissioner

Administrative Report No. 39

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APPENDIX I TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1940



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ADMINISTRATIVE REPORT SERIES

Since the beginning of the Administrative Report Series, considerable confusion has arisen concerning the system of numbering the separates composing it. Inasmuch as the Reports of the Divisions vary in order from year to year, many have found their designations as "Appendix No. I, II, III, or IV" very confusing. To relieve this, it has been decided to number them as "Administrative Report No. —." Inasmuch as 20 separates had already been printed in this series before starting the numbers, it was deemed advisable to begin the numbering with Administrative Report No. 21. Of course, numbers cannot be printed on those already off the press, but for the information of those who wish to know what the first 25 were, they are numbered for filing purposes as follows:

- No. 1. Report, Commissioner of Fisheries, 1931.
- No. 2. Alaska Fishery and Fur-Seal Industries, 1930.
- No. 3. Fishery Industries of the United States, 1930.
- No. 4. Progress in Biological Inquiries, 1930.
- No. 5. Propagation and Distribution of Food Fisheries, 1931.
- No. 6. Report, Commissioner of Fisheries, 1932.
- No. 7. Alaska Fisheries and Fur-Seal Industries, 1931.
- No. 8. Fishery Industries of the United States, 1931.
- No. 9. Progress in Biological Inquiries, 1931.
- No. 10. Propagation and Distribution of Food Fishes, 1932.
- No. 11. Alaska Fishery and Fur-Seal Industries, 1932.
- No. 12. Progress in Biological Inquiries, 1932.
- No. 13. Fishery Industries of the United States, 1932.
- No. 14. Propagation and Distribution of Food Fishes, 1933.
- No. 15. Fishery Industries of the United States, 1933.
- No. 16. Alaska Fishery and Fur-Seal Industries, 1933.
- No. 17. Progress in Biological Inquiries, 1933.
- No. 18. Propagation and Distribution of Food Fishes, 1934.
- No. 19. Alaska Fishery and Fur-Seal Industries, 1934.
- No. 20. Fishery Industries of the United States, 1934.
- No. 21. Progress in Biological Inquiries, 1934.
- No. 22. Propagation and Distribution of Food Fishes, 1935.
- No. 23. Alaska Fishery and Fur-Seal Industries, 1935.
- No. 24. Fishery Industries of the United States, 1935.
- No. 25. Propagation and Distribution of Food Fishes, 1936.

Note that the last Commissioner's Report was for 1932. Since then its place has been taken by a reprint from the Report of the Secretary of Commerce under the title "Bureau of Fisheries." Inasmuch as it is no longer a Bureau publication, it is not numbered; but it will be supplied to any who request the Report of the Commissioner for any year since 1932.

PROGRESS IN BIOLOGICAL INQUIRIES, 1939¹

By ELMER HIGGINS, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

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¹ Administrative Report No. 39, Appendix I to Report of the U. S. Commissioner of Fisheries for 1940. Approved for publication May 13, 1940.

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INTRODUCTION

Progress in biological inquiries during 1939 recounts numerous advances and extensions of scientific knowledge of the Nation's aquatic resources. From the research of the Division of Scientific Inquiry there is emerging a philosophy of fishery management that is finding direct application in State laws for the protection and development of the commercial fisheries and in the more active measures adopted for the rehabilitation and maintenance of the recreational fisheries.

The growth and expansion of fishery research throughout the almost 70 years that have elapsed since the establishment of the old U. S. Fish Commission is an interesting study. The early scientific investigations were either casual surveys or attempts to discover and to catalogue the aquatic resources. The strictly scientific surveys of the *Albatross*, the *Fish Hawk*, and the *Grampus* that bridged the end of the last and the beginning of the present century were paralleled by or followed by special investigations of specific phases of our inland water resources. From those studies there resulted a basic fund of oceanographic, ichthyological, and general zoological information. That basic research program has never ceased, for the spirit of discovery still persists throughout all of the Bureau's scientific endeavors.

The purely systematic and distributional studies of fishes and invertebrates of commercial importance did not long remain ends in themselves. It was not only necessary to know what we had but also how each item behaved in relation to its environment. Thus life-history and ecological studies of the most important fishes, molluscs and crustaceans were conducted with the object of obtaining information that would suggest means of insuring a continuation of the supply at a safe level of abundance. Statistical methods of analysis were adopted to interpret the large quantities of data that were accumulated. Fundamental concepts of fishery management were developed and applied and biological investigation thus become an indispensable tool of conservation.

The specific aim of the research concerned with both marine and fresh-water fisheries is an analysis of the fluctuations in natural abundance and production in an attempt to discover methods of balancing commercial yields against reproductive activities. In other words, the continuation of any fishery resource demands that an adequate breeding population always remain and that commercial production should remove only the surplus, or "annual crop."

Unfortunately, the depletion of many commercial fishery resources has been allowed to progress to a critical point before the financial support of investigation to discover means of protection was provided. Any attempts at rehabilitation based on scientific findings, necessarily are slow, especially since the fishing industry must be maintained at as high a level of production as is consistent with the preservation and recovery of the stocks. The research programs

concerned with the major commercial fisheries have been in progress for a sufficient time to enable recommendations for revised regulations and methods of management to be formulated.

Because the Bureau serves only as an investigative and advisory agency in most of the commercial-fishing areas, the practical application of recommendations is difficult and often tardy. More often than not, the general public has not been informed of the condition of the resources and the need for regulations. The lack of public appreciation permits the industry to oppose, unchallenged, constructive recommendations for legislation which they do not favor. The differences in the laws of States that border on the same waters are often a deterrent to the adoption of adequate conservation measures, for when the question of uniform laws arises the fishermen often clamor for the adoption of the regulations of that State which has the least stringent code. The problem of divided control seems much nearer a permanent solution at the present time than ever before. The success of international commissions, vested with full regulatory powers, in bringing about the recovery of depleted marine resources that are exploited in international waters is becoming well known. The recent authorization of interstate compacts by Congress for the purposes of formulating and enforcing conservation measures promises to provide a suitable vehicle for adequate control of fishery resources within the United States.

The invasion by recreational fishermen of marine and fresh-water areas formerly exploited principally by commercial fishermen has created additional problems for the fishery biologist. Angling has been conducted in commercial-fishing areas for a long time and the increase in intensity has perhaps been more gradual than the publicizing of the enterprise during the last several years would imply. Reliable estimates of the angling for certain commercially exploited species in areas of the Atlantic coast, the Great Lakes, and the Pacific coast indicate that the total annual catch of recreational fishermen may equal, at times, the catch of commercial fishermen. The magnitude of sport fishing conducted in some areas in competition with commercial fishing will necessitate the development of statistical procedure more complete than exists at present to measure the annual catches of both methods of fishing. An extension of the scope of research activities to consider the effect of angling on the natural abundance of heavily exploited species also will be imperative.

The cooperation of many States in the collection of reliable commercial fishery statistics is becoming greater each year. Records that enable the fishery biologist to study fluctuations in abundance in the major fishing areas are essential to the development of management procedures. Periods of unusual availability or of low levels of abundance can be anticipated if continuous and uniform statistical records that lend themselves to abundance analyses are available. A nation-wide and uniform State system for the collection of daily records of individual fishing enterprise for all commercial-fishing areas cannot be urged too strongly.

One of the important functions of the Division of Scientific Inquiry during recent years has consisted of cooperation with the Division of Fish Culture in projects related to artificial propagation of food and game fishes. From the "veterinary service" originally pro-

vided for hatcheries there has developed, in different parts of the country, a diversified cooperative program of assistance. Studies of hatchery disinfectants, methods of disease control, methods of fertilization, selective breeding, hatching, rearing, and planting, as well as feeding experiments and nutrition studies have been undertaken. The popularity of the processed publication, *The Progressive Fish-Culturist*, sponsored and edited by the Division, has continued to grow and it has become the principal means of disseminating practical and scientific information related to fish culture and fish management in fresh waters.

The studies of interior waters in relation to their value as angling resources constitute yet another phase of the Division's work. Unlike the commercial fishery investigations which were faced with critical conditions at the outset, the opportunity is afforded to assess many of the angling resources while they are in a healthy state. The accumulation of information related to the management of angling resources, stream improvement, and the formulation of stocking policies has progressed as rapidly as the limited funds and investigative personnel will permit. The related studies of the effects of pollution of all kinds have been advanced significantly both through controlled laboratory experimentation and ever-widening field investigations. A comprehensive study of the effects of larvicides and insecticides on fish populations has yielded important conclusions.

COOPERATION

The scope of the investigational activities of the Bureau has become so broad and diversified, as indicated by the preceding general discussion and the detailed reports which follow, that neither the appropriations nor the staff are adequate to carry on the work unaided. The cordial relations with many colleges and universities and their generous provision of laboratory space, equipment, and other facilities have enhanced the work of the Division for many years.

The material cooperation of a number of States, various State agencies, and of many establishments of the Federal Government has continued in greater measure than ever before. The U. S. Forest Service, the Bureau of Reclamation, the War Department, the Coast Guard, and the Tennessee Valley Authority have been concerned in cooperative undertakings during the past year. The Council of State Governments has continued to provide active assistance to the Bureau and to various States in the promotion of interstate and international cooperation in the development of means and measures for the preservation of the Atlantic coast and Great Lakes fisheries. The North American Council on Fishery Investigations, composed of representatives of the United States, Canada, Newfoundland, and France, held no meetings during the year because of the war in Europe. The organization remains active, however, and regular meetings will be resumed as soon as conditions permit.

PUBLICATIONS

Although substantial progress has been made in all of the Division's many fields of investigation, and a number of manuscripts were completed during the year, the available funds for printing

were so limited that the actual dissemination of printed information was extremely meagre. There are on file a large number of manuscripts which represent an investment in time and materials many times as great as the cost of publication. The reports of the investigations that have been completed are sorely needed as scientific references and as sources of information for management and legislation. The practical value of many of these unpublished reports will diminish gradually through the protracted delay in publication, but, fortunately, their scientific worth will suffer little. The very scanty number of scientific publications by the Bureau during recent years does not reflect the constantly expanding responsibilities and the continuous improvement in the calibre of the investigative personnel.

The following publications appeared in the Bureau's series during 1939:

BELL, FRANK T., and ELMER HIGGINS.

A plan for the development of the Hawaiian fisheries. Investigational Report No. 42, 25 pp., 3 figs.

GALTSOFF, PAUL S., and VICTOR L. LOOSANOFF.

Natural history and method of controlling the starfish (*Asterias forbesi*, Desor). Bulletin, U. S. Bureau of Fisheries, vol. XLIX, No. 31, pp. 75-132, 32 figs.

HIGGINS, ELMER.

Progress in biological inquiries, 1938. Administrative Report No. 35, 81 pp.

PEARSON, JOHN C.

The early life histories of some American Penaeidae, chiefly the commercial shrimp, *Penaeus setiferus* (Linn.). Bulletin, U. S. Bureau of Fisheries, vol. XLIX, No. 30, pp. 1-73, 67 figs.

The following papers were published by members of the staff of the Division of Scientific Inquiry, during the year 1939, in journals of other organizations:

CRAIG, J. A.

Critique on Fisheries. The Pacific Northwest: A selected bibliography. The Northwest Regional Planning Council. 1939. Portland, Oreg.

DAVIDSON, FREDERICK A.

The conservation of the Alaska salmon fisheries. The Military Engineer, vol. 31, No. 176, 1939, pp. 109-111, 3 figs.

Why it's important to protect our salmon. Alaska Life, vol. 2, No. 1, February 1939, pp. 8-9, 18; 1 fig., map.

DAVIDSON, FREDERICK A., and A. E. VAUGHAN.

Cyclic changes in the time of the southeast Alaska pink salmon runs. Pacific Fisherman, Feb. 1939, pp. 22-24 (pt. 1); Mar. 1939, pp. 40-42 (pt. 2); Apr. 1939, p. 39 (pt. 3).

DEASON, HILARY J.

Report of the Division of Commercial Fishing. Transactions, American Fisheries Society, vol. 68, 1938 (1939), pp. 27-30.

The distribution of cottid fishes in Lake Michigan. Papers, Michigan Academy of Science, Arts and Letters, vol. XXIV, pt. II, 1938 (1939), pp. 105-115.

FIRTH, FRANK E.

A record size (480 mm.) John dory (*Zenopsis ocellatus*) with notes on its distribution in our North and Middle Atlantic waters. Zoologica, vol. XXIV (pt. II), Oct. 1939, pp. 383-384. 1 fig.

FISH, FREDERIC F.

Notes on *Myxobolus inornatus* n. sp., a myxosporidian, parasitic in the black bass (*Huro floidana* Le Sueur). Transactions, American Fisheries Society, vol. 68, 1938 (1939), pp. 173-177.

Simplified methods for the prolonged treatment of fish diseases. Transactions, American Fisheries Society, vol. 68, 1938 (1939), pp. 178-187.

GALTISOFF, PAUL S.

The new Milford laboratory of the Bureau of Fisheries. Science, vol. 90, No. 2338, 1939, p. 365.

GALTISOFF, PAUL S., H. H. BROWN, C. L. SMITH, and F. G. SMITH.

Sponge mortality in the Bahamas. Nature, vol. 143, 1939, pp. 807-808.

GINSBURG, ISAAC.

The measure of population divergence and multiplicity of characters. Journal, Washington Academy of Sciences, vol. 29, 1939, pp. 317-330.

Two new gobioid fishes collected on the Presidential cruise of 1938. Smithsonian Miscellaneous Collections, vol. 98, No. 14, 5 pp., 2 figs.

HILDEBRAND, SAMUEL F.

An annotated list of the fishes collected on the several expeditions to Greenland, the Fox Bay region, and the coast of Labrador by Captain R. A. Bartlett, from 1925 to 1935. Meddelelser om Grønland, Bd. 125, Nr. 1, 1939, 12 S.

The Panama Canal as a passageway for fishes, with lists and remarks on the fishes and invertebrates observed. Zoologica, vol. XXIV, pt. I, art. 3, 1939, pp. 15-45, 2 pls.

LOBELL, MILTON J.

Report on certain fishes: winter flounder (*Pseudopleuronectes americanus*). In: A Biological Survey of the Salt Waters of Long Island, 1938. Pt. I. Supplement to Twenty-eighth Annual Report, New York Conservation Department, 1939, pp. 63-96.

NEEDHAM, PAUL R.

Migratory fishes and dam construction in West coast waters. Transactions, Fourth North American Wildlife Conference, 1939, pp. 300-304.

Natural propagation versus artificial propagation in relation to angling. Transactions, Fourth North American Wildlife Conference, 1939, pp. 326-331.

NEEDHAM, PAUL R., and H. J. RAYNER.

The experimental stream, a method for study of trout planting problems. Copeia, 1939, No. 1, March, pp. 31-38.

NESBIT, ROBERT A.

Report on certain fishes: weakfish (*Cynoscion regalis*). In: A Biological Survey of the Salt Waters of Long Island, 1938. Pt. I. Supplement to Twenty-eighth Annual Report, New York Conservation Department, 1939, pp. 97-106.

NEVILLE, WILLIAM C.

Description of Long Island. In: A Biological Survey of the Salt Waters of Long Island, 1938. Pt. I. Supplement to Twenty-eighth Annual Report, New York Conservation Department, 1939, pp. 11-14.

NEVILLE, WILLIAM C., CHARLES L. DICKINSON, and JAMES R. WESTMAN.

Miscellaneous species. In: A Biological Survey of the Salt Waters of Long Island, 1938. Pt. I. Supplement to Twenty-eighth Annual Report, New York Conservation Department, 1939, pp. 107-152.

NICHOLS, J. T., and FRANK E. FIRTH.

Rare fishes off the Atlantic coast including a new grammicolepid. Proceedings, Biological Society of Washington, vol. 52, June 5, 1939, pp. 85-88.

NIGRELLI, ROSS F., and FRANK E. FIRTH.

On *Sphyrion lumpi* (Krøyer), a copepod parasite on the redfish, *Selastes marinus* (Linnaeus), with special reference to the host-parasite relationships. Zoologica, vol. XXIV, pt. I, Apr. 1939, pp. 1-10, 4 pls.

PERLMUTTER, ALFRED.

An ecological survey of young fish and eggs identified from tow-net collections. In: A Biological Survey of the Salt Waters of Long Island, 1938. Pt. II. Supplement to Twenty-eighth Annual Report, New York Conservation Department, 1939, pp. 11-71, 8 figs.

SUMNER, FRANCIS H., and OSGOOD R. SMITH.

A biological study of the effect of mining debris dams and hydraulic mining on fish life in the Yuba and American Rivers in California. Report submitted to U. S. District Engineer's Office, Sacramento, Calif., May 1, 1939, 51 pp., 14 figs., 3 maps. [Mimeographed.]

SURBER, EUGENE W.

A comparison of four eastern smallmouth bass streams. Transactions, American Fisheries Society, vol. 68, 1938 (1939), pp. 322-333.

VAN OOSTEN, JOHN.

A common concern—Great Lakes fisheries for anglers and fishers. Michigan Game Trails, vol. 1, No. 5, 1939, p. 1.

Battle rages over closing Potagannissing Bay to commercial fishermen. Michigan Game Trails, vol. 1, No. 3, 1939, pp. 19-20.

Can the Great Lakes fisheries be saved? American Wildlife, vol. 28, No. 3, 1939, pp. 129-135.

Migratory fish, a problem of interstate cooperation? Transactions, Fourth North American Wildlife Conference, 1939, pp. 25-30.

Save the Great Lakes fisheries! Outdoor America, January, 1939, 2 pp. [Also appears in: Congressional Record Appendix, March 24, 1939, pp. 4588-4589.]

The age, growth, sexual maturity, and sex ratio of the common whitefish, *Coregonus clupeaformis* (Mitchill), of Lake Huron. Papers, Michigan Academy of Science, Arts, and Letters, vol. XXIV, pt. II, 1938 (1939), pp. 195-221.

VAN OOSTEN, JOHN, and HILARY J. DEASON.

The age, growth, and feeding habits of the whitefish, *Coregonus clupeaformis* (Mitchill), of Lake Champlain. Transactions, American Fisheries Society, vol. 68, 1938 (1939), pp. 152-162.

WESTERMAN, FRED A., and JOHN VAN OOSTEN.

Report to the Michigan State Senate on the fisheries of Potagannissing Bay, Mich. Michigan Department of Conservation, Lansing. 82 pp.

MULTILITHED PUBLICATIONS

HERRINGTON, WILLIAM C., H. M. BEARSE, and FRANK E. FIRTH.

Observations on the life history, occurrence, and distribution of the red-fish parasite *Sphyrion lumpi*. Special Scientific Report No. 5, 12 pp., 6 figs.

U. S. BUREAU OF FISHERIES.

The Progressive Fish-Culturist. Memorandum I-131. 5 issues.

Progress reports of the investigations conducted by the various sections, prepared in the main by the section heads, are presented in the following pages:

NORTH ATLANTIC FISHERY INVESTIGATIONS

WILLIAM C. HERRINGTON, *in charge*

The situation of the offshore fisheries in the North Atlantic region was somewhat better in 1939, on the whole, than during 1938. The total catch, as shown by landings at Boston, Gloucester, and Portland, was nearly as great as in the previous year in spite of labor difficulties which caused temporary tie-ups. The catch reached 389,000,000 pounds, about 3 percent less than in 1938, but, due to higher average prices, it brought the fisherman more than \$9,300,000, an increase of nearly 7 percent over the 1938 value. This offshore catch landed at the three principal New England ports represents more than half of the total New England poundage of fish and shellfish. In 1937 it amounted to about 60 percent of the total weight and 50 percent of the total value of the New England catch.

The shipbuilding boom of the past few years, which included the construction of a large number of new otter trawlers of the "super trawler" class, did not continue in 1939. In contrast, there was a shrinkage in the fleet of large otter trawlers, since many of the old steamers were disposed of. By the end of the year only 6 steamers remained in operation out of a one-time total of around 40 boats. The decommissioning of old boats balanced the new construction approximately, so that total fishing intensity due to the large boats was about the same in 1939 as in the previous year.

The great fisheries of the North Atlantic have been subject to tremendous fluctuations in yield since the early days of the fishing industry, yet neither the extent of these changes nor their causes and probable duration have been known. An understanding of these factors, based on a comprehensive study of the biology and catch records of the important species, is necessary to maintain the fisheries at a high productive level or to suggest corrective measures in instances of overexploitation. Studies of the mackerel and haddock offshore fisheries have been under way for several years, and recently have been started on flounders. A much needed general study of the fluctuations in abundance of other groundfish was begun in 1938. No biological work has been possible recently on the important fisheries for cod, redfish, pollock, and swordfish.

The biggest handicap to the understanding of present trends in the extensive inshore fisheries of the North Atlantic coast is the lack of adequate catch statistics to provide a measure of changes in abundance. The most important problems involve the improvement or maintenance of the fisheries for flounders, lobster, haddock, cod, and salmon, which form the chief means of support for the coastal communities on long sections of the New England coast.

Cooperation with various State organizations has increased and has proved very satisfactory and productive. In addition to assisting in the inauguration of a general State system for collecting current catch records, the staff cooperated in various other projects. The most significant undertaking was the lobster investigation. The lobster fishery is an extremely important resource from Maine to New Jersey, and is second in value only to the haddock fishery in the region as a whole. In spite of the fact that it has been generally admitted for some time that the lobster fishery was in a serious condition, and has been subjected to regulation for many years, little biological work has been done recently to develop a sound basis for intelligent management. In order to obtain much needed information concerning improved rearing technique and the value of various regulations, the Maine Department of Sea and Shore Fisheries turned over to the Bureau a fund to cover the salary of a biologist to work in this field. The Bureau has provided the other expenses of the investigation.

Working in cooperation with several State officials, an annual lobster conference has been organized to bring together representatives of the industry and conservation departments of the interested States for a discussion of mutual problems and development of progressive and uniform conservation regulations. Meetings were held in February and July, 1939.

The past year witnessed increased interest in the restoration of Atlantic salmon. At the request of the National Wildlife Federation, W. C. Herrington and Dr. G. A. Rounsefell, in cooperation with Mr. George H. Stobie, Maine Commissioner of Inland Fisheries, and representatives of other North Atlantic States, prepared a long-period, cooperative program designed to restore and maintain salmon runs in the most favorable New England streams. It is hoped that the concentration of support behind one sound basic program will make it possible to get something definite started by the States and the Bureau in the near future.

During the past year an extra effort was made by the North Atlantic staff to develop a more widespread knowledge of and interest in the marine fisheries problems of the region. Working in cooperation with Dr. Daniel Merriman, of Yale University, a marine section was added to the annual meeting of the New England Game Conference.

After 8 years with no sea-going equipment, the Division finally obtained a 41-foot hull by transfer at Boothbay Harbor from the Division of Fish Culture. With the assistance of Supt. Thomas Dorr and his crew, the boat has been renovated, a cabin and engine room added, and an engine installed. She was christened *Skimmer*, and will be used in inshore waters principally for flounder work. However, the major contribution to our fleet came through a gift of the 152-foot steam trawler *Harvard* from the General Seafoods Corporation. This boat was built in 1926, and although the hull was in good condition, had been tied up for several months due to the relatively high cost of operating steam-powered trawlers, compared to Diesel-powered. A grant of \$125,000 has been obtained from the P. W. A. and this boat, which has been named *Albatross III*, will be renovated during 1940.

Commissioning of the *Albatross III* will make it possible to undertake annual surveys of the fishing grounds from Cape Cod to the Newfoundland Banks. These surveys will provide information on the abundance and distribution of the various species of marketable fish and will enable us to assess the strength of year classes 1 and 2 years before they enter the commercial fishery. Numerous problems connected with the mackerel investigation, tagging, and gear experiments also can be attacked.

Although good progress is being made in the various investigations, in many cases the work has been seriously limited by the lack of sufficient technical and clerical assistance to collect and analyze the data required for certain phases of the work. W. P. A. projects Nos. 365-14-3-4 and 702-3-2, which expired in the spring of 1939, and No. 765-14-3-20, which was begun on July 5, 1939, have made possible the continuation of the compilation and charting of statistics bearing on the development of the New England fisheries and the analysis of the records of the haddock fishery for early years, as well as a study of the early groundfish fishery.

The headquarters of the North Atlantic Fishery Investigations has remained in Cambridge and Boston, Mass. Harvard University has generously provided the staff with space and facilities in its biological laboratories. The cooperation of the Woods Hole Oceanographic Institution is gratefully acknowledged, as is the personal advice and interest of Prof. Henry B. Bigelow. The assistance and cooperation of fishermen and dealers in providing the use of their records, and in other ways, is also acknowledged with pleasure.

MACKEREL

Catch records indicate that mackerel landings on the Atlantic coast in 1939 were considerably less than in 1938. This decrease is shown by receipts of mackerel at the three principal New England ports, Boston, Gloucester, and Portland; 20,887,000 pounds in 1938 compared to 12,319,000 pounds in 1939. In 1935, the last year of high mackerel landings, 45 percent of the total Atlantic coast mackerel catch was landed at these ports. To the fishermen, this drop in land-

ings was accompanied not by a price increase, but by a slight decrease; the average being 2.8 cents per pound in 1938 and 2.6 cents per pound in 1939.

Conditions in the mackerel fishery have not been encouraging to owners of New England vessels which annually account for more than one-half of the total mackerel production. The last 5 years have witnessed a steady decline in the number of purse seiners entering the mackerel fleet; in 1935, there were 99, but only 49 in 1939. Most of the 50 vessels lost to the mackerel fishery have taken up groundfish dragging. Dependable profits to fishermen in a well-established rosefish fishery, especially, have offered relief from the uncertainties of the mackerel supply and discouraging financial returns. Such uncertainties are not new to the mackerel fishery. Violent fluctuations in the catch from one year to the next have bothered the trade and the fishermen for more than a century.

The mackerel investigation begun in 1926 had for its purpose the discovery of causes for the great differences in annual yield, with a view toward turning its findings to economic advantage. Several lines of investigation were inaugurated for solution of the problems. These were: (1) The collection of catch records, to provide a means of comparing past with present production of mackerel. (2) The determination of a measure of abundance not affected by changes in the size of the fleet or the amount of gear fished. (3) The study of such salient features of mackerel biology as might have a bearing upon the problem; geographical distribution, spawning habits, rate of growth, life span, migrations, etc. (4) A study of conditions in the sea to determine what environmental factors influenced appreciably the biological features mentioned above.

Catch records assembled from many sources revealed an 80 to 100 million-pound production level, roughly speaking, from 1804 to 1885. This was the "hey-dey" of the fishery, when annual production occasionally exceeded 100,000,000 pounds. The last such peak, in 1884, was followed by a drop to about 25,000,000 pounds in 1886. Since that time mackerel production has averaged approximately 30,000,000 pounds a year. The last good year was 1935, when total Atlantic coast landings approximated 80,000,000 pounds. In 1937, the total production was about 25,000,000 pounds.

Mackerel first appear off Virginia in the spring, and are found progressively northward to the Gulf of St. Lawrence as summer advances. The offshore fishery rarely extends more than 100 miles from shore, while the activity of the fleet is confined largely to a strip of water averaging less than 50 miles from the coast. With the approach of cold weather, mackerel apparently leave the Gulf of St. Lawrence and head southward. Until 3 years ago the fishery had ceased off southern New England by the end of December. During the past 3 years, however, a few purse seiners have continued operations into January.

Observations have demonstrated that spawning in the southern part of the range takes place between April and August. Due to rapid summer growth, mackerel attain minimum marketable size their first fall; about 8 or 9 inches in length. As a rule, the maximum size attained is about 22 inches in length and about 4 pounds in weight, during a life span of approximately 12 years.

Although no direct measure of mackerel abundance has been found, their availability to the purse-seine fishery has been taken as roughly indicative of abundance under actual conditions. Of course, this fails to measure adequately the availability except where the fleet is fishing. The strictly shoreward dispersal of the species, and its distribution on distant banks, has not been measured.

During the course of the investigation it was found that the make-up of the commercial fishery in any year was predominantly mackerel of one or two year classes. Sometimes a single year class has been important to the catch for as long as 5 years. In other seasons the year class of most importance has been of a transitory nature, appearing for but one year and then dropping out of the catch quite rapidly.

Observations indicated two principal factors that control mackerel abundance—the recruitment of new year classes to the fishery, and the losses due to mortality. Having obtained a measure of these factors, a series of fairly successful catch forecasts was begun in 1931. In 1937, however, the catch by the vessel fishery fell about 40 percent below the prediction. Since this circumstance indicated the operation of unknown factors, forecasts have been discontinued pending further research to discover them.

Progress during 1939.—The mackerel investigation in 1939 was under the direction of John R. Webster, who was assisted by Frank E. Firth. Analysis of the commercial landings showed three size groups in the mackerel populations during 1938—the year class of 1937, the year class of 1936, and a mixed group of year classes from 1934 to 1930. No one group dominated the catch for an entire year. All groups exhibited marked increases in availability compared to the previous year which averaged about 500 percent for the 1937 and 1936 year classes, and more than 100 percent for the mixed group of older fish.

The causes of such an increase in availability must be found in environmental conditions. To be caught by purse seiners, mackerel must be sighted while they school at the surface. Records of surface-water temperatures at lightships along the New England coast during the summer of 1937 were above normal, sometimes by as much as 7° F. It was at this time that the mackerel catch fell off the most. Temperatures during the summer of 1938 were near or slightly below normal.

The spring purse-seine fishery shifts its activity from the Middle Atlantic area to the Gulf of Maine as rapidly as mackerel become commercially available there. The question arises as to whether abundance of the shore run of mackerel keeps pace with that of off-shore populations. Progress in solving this problem has been made through the assembling of trap-catch records for 1937 and 1938 covering the coast from Virginia to Massachusetts. The records indicate that considerable numbers of mackerel persisted in the Middle Atlantic region for at least 2 months after seiners in the spring fishery quit the region.

Field work in 1939, conducted principally by Mr. Firth, was confined largely to securing measurements, scale samples, and interviews with boat captains who landed catches. Data were secured in New Jersey and New York in April and May, and at the Boston Fish Pier

during the remainder of the year. Sufficient data concerning 675 mackerel trips were secured by interview to provide representative information concerning fleet activity. A total of 49,000 mackerel measurements will form a basis for population studies, and 450 scale samples will enable age determinations to be made.

Considerable difficulty has been experienced in developing a suitable tag and tagging technique, for mackerel in order to study the migration problem. Several kinds of tags have been tried, but they have yielded discouragingly low percentages of returns. Experiments conducted by Mr. Webster at Woods Hole in August indicated, beyond reasonable doubt, that the chief problem of tagging is one of handling mackerel properly.

HADDOCK

The North Atlantic haddock fishery of the United States extends from the coast of southern New England to the western portion of the Grand Banks, and in the past 13 years has produced between 150 and 250 million pounds annually. The peak years came between 1928 and 1930, but they were followed by a rapid decline to approximately 150 million pounds in 1932. Since 1932 the catch never has approached the 1928-30 level. The fishery in 1939 was comparatively successful from the point of view of the industry. The total catch of 135 million pounds landed at Boston, Gloucester, and Portland (which accounts for 80 to 90 percent of the United States total) was slightly higher than in 1938 in spite of labor troubles which tied up many of the large trawlers for several weeks. Prices averaged about 11 percent above 1938, so that the total value of the above catch reached \$3,693,000. The increase in the price of scrod was particularly noticeable, for after a poor start during the period January-March the price rose above that of the previous year and maintained the advantage for the balance of the season. The average increase for the year was 35 percent.

Two-thirds of the 1939 catch came from area XXII So. (Georges Bank and South Channel) and present experience indicates that on the average this area will continue to supply the bulk of the New England haddock catch in the predictable future. Prior to 1935, between 70 and 90 percent of the catch ordinarily came from this area. However, the appearance of the tremendously abundant 1929 year class on the Nova Scotian Banks caused a shift of fishing activities which reduced the Georges catch in 1934 to 30 percent, and in 1935 to 40 percent of the total. With the exhaustion of this great year class, there has been a progressive shift of fishing activity back to Georges Bank. As no year class comparable to that of 1929 has been observed on the Nova Scotian Banks in subsequent years, while several have appeared on Georges Bank, it would appear that the latter bank is more regularly productive than the former, and, except for limited intervals, will continue to be our principal source of supply. The trend back to Georges Bank in 1939 was stimulated by the campaign for an improvement in the quality of fish and has emphasized the importance of short trips. This makes fishing on Georges Bank particularly advantageous, since most of the bank is less than 1 day's run from Boston.

The Grand Bank fishery still seems to be beyond the practical range of our fleet. Several scouting trips were made to this area during 1939, but the distance is so great that the catches ordinarily do not justify the extra time and fuel consumption.

The unfortunate trend toward concentration of the fishery on small haddock has continued, and in recent years the fleet has taken an increasing quantity of scrod haddock. This size category made up 25 percent of the total catch in 1937, 32 percent in 1938, and 38 percent in 1939. On Georges Bank alone, the proportion ran even higher—43 percent in 1939. The increased capture of scrod is definitely prejudicial to the future of the haddock fishery, since haddock of the small sizes affected are growing rapidly, and another year on the bank would increase materially the poundage in the sea available to the fisherman. The increased concentration on scrod will reduce even further the supply of haddock available.

It was demonstrated early in the present investigation that although the great decline in catch immediately following 1930 was partly due to economic factors, the principal cause was the scarcity of haddock as compared to earlier years. The major problems to be solved are the detection of the causes of the scarcity, whether due to natural conditions or to the commercial fishery, and the determination of how these causes could be controlled so that the fishery might be restored and maintained at the most productive level.

In attacking these problems, a consistent program of investigation has been pursued which stresses the following points: (1) The collection and compilation of present and past records to show the total quantity of haddock taken by the commercial fishery from each of the principal fishing grounds. (2) The development and application of an index of abundance to show accurately the changes in the stocks of fish, rather than changes in gear or fishing methods. (3) A determination of the relative success of reproduction from year to year and its relationship to measurable features of the natural environment. (4) A determination of the interdependence of haddock stocks through study of the passive movements of eggs and larvae and the migration of bottom stages. (5) A study of features of the biology of the species, such as growth rates, mortality rates, and distribution, that are needed to interpret the various population data. (6) An analysis of modifications in fishing procedure to determine the most practical and effective methods for obtaining an optimum yield. This involves experiments with savings gear, the charting of nursery grounds, and related projects.

Extensive records of fishing activities of the otter-trawl fleet from 1914 to the present were accumulated from various public and private sources. After considerable analysis, a method of calculating the relative abundance from year to year was developed which gave consistent results in spite of changes in fishing intensity from month to month and from year to year. By use of this method an index of abundance, or availability, was nearly completed for 1914-37. This index demonstrates that in the Georges Bank region regular cycles in abundance of commercial-sized haddock occurred in the early years of the fishery before the fishing intensity had become severe. These cycles of 7 to 9 years in length were caused by similar cycles in the success or failure of the survival of young to commercial size. The cycles in the survival of young tentatively

appear to be correlated with the magnitude of the adult stock, with poor survival in years of extremely high as well as of low abundance of adults, and good survival in years of intermediate abundance. There are other apparently noncyclic variations from year to year which appear to be due to features of the physical environment.

The precipitous drop in haddock abundance during the years 1929 to 1931 was due to the coincidence of a period of greatly increased fishing intensity and that portion of the natural cycle having a minimum replacement of young. Consequently, with a heavy drain from the commercial fishery and negligible replacements of young fish, the abundance of marketable haddock declined at a rapid rate. Following the low level reached in 1931 the abundance has recovered to some extent, but has failed to build up to levels comparable to the 1926-28 period since the commercial fishery has been so intensive that no considerable accumulation of market-sized haddock was possible.

Information concerning the haddock populations off the Nova Scotian coast is much less complete, for our fleet fished this area only sporadically until 1933-34, and practically no fishing was done in the area during the years of high abundance on Georges Bank. Therefore, the continuous measure of abundance available for Georges Bank is not available for the Nova Scotian coast.

A large amount of subsidiary biological information, discussed in previous annual reports, has been obtained to assist in the explanation and understanding of the abundance cycles.

Progress during 1939.—The investigation was continued under the direction of Mr. Herrington with the part-time assistance of H. M. Bearse and M. S. Moses. Dr. Rounsefell continued the Maine tagging experiment begun in 1938. Field work was limited mainly to the collection of the basic data required for determining the age, number, and size composition of the 1939 catch, since analysis of abundance now is included in the groundfish studies. During the course of the year Mr. Bearse obtained length measurements of nearly 50,000 haddock and collected 3,500 haddock scale samples.

Laboratory work was concentrated on the completion of the haddock abundance index from 1914 to 1937 and the compilation of a record of the total monthly haddock catch from the Georges Bank and Nova Scotian areas for the same period. Records of total monthly haddock catches were obtained from Bureau records for Boston, Gloucester, and Portland, and from records of fishing companies for New York and Groton. These records account for nearly the entire offshore haddock catch. The compilations are required to show the total fishing strain and for use in evaluating the effect of increased gear competition.

Completion of the primary stage of computing the abundance index required special analysis to compensate for certain gaps in our data for 1914 to 1916. Portland landings, shown only as total haddock, were divided into large and scrod on the basis of hauled weights. Statistical analysis showed that this method was consistently accurate. The running time between port and fishing grounds, which is required for our calculation of fishing effort, was obtained from the length of trip since data for 1917 to 1920 showed that there was a high degree of correlation between these two components of a trip.

In the more complete records and refined analysis for late years, a number of minor difficulties were solved. The validity of variations in our records of "lost time," the most subjective of the factors used in our computation of "catch per unit of fishing effort," was established through comparing the percentage lost time with percentage wind force of 7 or more, as reported by lightships. A correlation of 0.91 between these variables indicated that the variations in lost time were due to weather and not to personal factors. Shifts within the season between Georges Bank and the more distant grounds were found to be closely correlated with water temperatures, apparently due to the difficulty in keeping fish on long trips during the summer, when water temperatures are high. This work completed the primary analysis of our data to show catch per day by months.

The next major step in the abundance analysis was to summarize the data by seasons and years. Preliminary attempts, using the usual arithmetic averages and direct combination, proved unsatisfactory due to monthly differences in level of availability, combined with great variations in the amount of fishing carried on in the several areas and from month to month. The availability through the season was found to follow a consistent pattern throughout the 24 years studied. However, it was found that in years of scarcity the winter fishery suffered much more than the summer, since at such times the winter catch declined 40 percent more than the summer. It was determined that the best seasonal grouping was by 3-month periods, beginning in February. Using this grouping and a weighted-ratio method of combining monthly data which takes care of variations from month to month in the amount of fishing, the seasonal and yearly summarization was completed for the Georges Bank area.

The final step in the preparation of the index curve is an adjustment for the various changes in fishing methods and apparatus that were introduced from 1914 to 1937 in order to make the data on catch per day comparable over the entire period. The adjustment for these changes is of prime importance, since some of the most vital conclusions concerning the productivity of the stock at different levels of abundance depend on a correct determination and comparison of the levels of abundance in early and in recent years.

Most of the work on evaluation of the above changes was completed during 1939. The increased size and power of the trawlers was taken into account by using specific groups of boats over a protracted period, and when forced through obsolescence of boats to change from one group to another the activities of the two groups were overlapped to obtain a measure of relative effectiveness. There also was a change from steam to Diesel power involving a decrease in both gross tonnage and horsepower, but no appreciable change in effectiveness. The effect of Vigneron-Dahl gear, adopted by most of the boats between 1927 and 1931, was evaluated by comparing the productivity of groups of boats before and after installation of this gear. Results showed that the new gear increased performance by at least 29 percent during the winter, and probably more in summer. Evaluations of the influence of the radio, fathometer, and gear competition were partly completed. A study of the effect of changes in the proportion of other species in the catch was partially completed.

Tagging.—The tagging experiments commenced in 1938 by Dr. Rousefell were continued. In June 1938, 628 haddock were tagged and released off Mt. Desert Island, Maine, and in June 1939, 538 additional fish were marked in the same locality. Recoveries from both experiments indicate that haddock taken by hook and line from a small boat—insuring careful individual handling—can be tagged successfully when fishing in depths up to at least 30 fathoms. Tagging of fish caught at greater depths has not been attempted. When the new research vessel is completed, the same technique may be applied to the haddock on the shoaler parts of the offshore banks.

Of the number of fish tagged in 1938 experiment, 10 percent were recaptured. Three types of tags were employed and the recoveries consisted of 11.4 percent of the celluloid-disk type, 9.5 percent of the "bachelor button" type, and 8 percent of the internal-anchor type, but the differences in the percentages of recaptures of fish marked by the three methods are not statistically significant. In the 1939 experiment, from which recoveries are still coming in, 10.2 percent of the disk type and 7.3 percent of the button type have been taken to date. The disk type thus seems to be proving slightly superior to the button. In the 1938 experiment, 49 percent were recaptured more than 90 days after their release, 38 percent more than 200 days, and 10 percent more than a year later.

In the 1938 experiment, the locality of recapture was available for 60 of the 63 recoveries. Of these, 52 percent were recaptured within 10 miles of the point of liberation and 65 percent within 20 miles. However, several long migrations were performed, so that although the median distance traveled was only 7 miles, the average distance was 36.7 miles. Since the 1939 experiment has run for only 8 months, the dispersion will not be discussed.

During the summer months the haddock showed a tendency to migrate southwestward along the Maine coast. From the time of their release in June to the end of October there were 37 recaptures at known localities, of which 30 were taken within 20 miles of the point of release, and 7 from 30 to 85 miles to the southwest. From Feb. 28 to May 10, 1939, 6 were taken on Browns and Little La Have Banks, from 137 to 182 miles southeastward of the point of release. This indication of a southeastward spring migration is confirmed largely by the fact that Browns Bank, fished throughout the year, yielded recoveries at only the one season. The recovery of two tags on Georges Bank raises the question of whether the haddock crossed the deep Fundian Channel, separating Browns and Georges Banks, or whether they followed a long, roundabout course by way of Cape Cod and Nantucket Shoals (one fish was taken 130 miles southwestward, on Jeffrey's Ledge), or crossed directly over the Gulf of Maine.

FLOUNDER

The flounder fishery of the North Atlantic States is based chiefly on 5 species: (1) The lemon sole, *Pseudopleuronectes dignabilis*; (2), the winter flounder or blackback, *P. americanus*; (3), the grey sole or witch, *Glyptocephalus cynoglossus*; (4) the yellowtail, *Limanda ferruginea*; and (5), the dab, *Hippoglossoides platessoides*. In 1937, the most recent year for which complete figures are available, the total catch of flounders reached 59,000,000 pounds, worth nearly

\$2,500,000 to the fishermen. Yellowtail contributed the largest poundage (15,000,000 pounds), closely followed by the winter flounder (13,500,000 pounds). The winter-flounder catch was the most valuable (\$522,380) followed by the grey sole catch (\$510,046).

The greater part of the flounder catch comes from the inshore fishery. In 1937 less than one-third of the total catch was landed at Boston, Gloucester, and Portland by the offshore fleet fishing out of those ports. Consequently, the species of flounder are of great importance to the small-boat and shore fisheries, and during recent years have become of increasing interest to a growing army of sport fishermen, particularly from Cape Cod to Long Island waters.

In 1938 the New York State Conservation Department undertook a survey of the marine fisheries in New York waters. Although the State survey ended in Dec. 1938, Suffolk County, which includes the major part of Long Island waters, provided funds to continue the work on their fisheries until June 1940. A report of the cooperative investigation appears on pp. 27-29 of this publication.

In view of the importance of commercial and sport fishing for winter flounders south of Cape Cod, and the financial cooperation of New York State, it has been decided for the time being to concentrate the work on the winter flounders in that area. It is hoped that facilities will be available in the future to extend the work to other areas and species.

Numerous reports indicate a serious decline in abundance of the winter flounder. To obtain some measure of this decline, determinations of the total catch and catch per unit of effort over a long period of time must be made in order to determine the condition of the stock and fluctuations in the fishery. To discover the factors that influence fluctuations, such biological phases as racial composition of stocks, age and growth, migrations, success of spawning, etc., must be studied.

Progress during 1939.—Better records of flounder landings are available for 1939 than ever before, through the action of Maine and Connecticut in installing a system for the collection and publication of monthly records of their fish catches. The coverage of several important flounder ports in Massachusetts also was improved through the collection of records of landings by the Bureau's Market News agents. These developments are of great importance to the flounder work, since the greatest part of the catch of these species is landed at minor ports and is not covered by the Bureau's records for Boston, Gloucester, and Portland.

The excellent reports of landings at the three principal New England ports do not show the fish landed at "T" Wharf, Boston, which include large quantities of flounders. A temporary assistant was detailed to cover "T" Wharf for the month of February to determine the magnitude of the landings. The 4-week total reached 248,000 pounds. According to information obtained from dealers, landings during the summer are considerably higher. Thus, it appears that more than 3 million pounds of fish per year are not included in the Boston reports.

Returns continued to come in from fish tagged in Great South Bay, Great Peconic Bay, Gardiners Bay, and Long Island Sound, in New York waters, as well as from fish tagged in Connecticut and Rhode

Island waters. During 1939 a series of fish also was tagged in John's Bay, Maine. In general, tagging experiments indicate offshore migrations of the winter flounder in the spring, and inshore spawning migrations in the fall. Although there was some slight dispersion of fish from local areas, the majority never ventured far from home waters.

Racial studies of the flounders in the Long Island area, during the summer of 1939, confirmed the existence of local populations in the Peconic Bay, Great South Bay, and Long Island Sound regions, as indicated by the tagging experiments.

ANALYSIS OF GROUND FISH ABUNDANCE

The groundfish abundance analysis was continued under the direction of Dr. Rounsefell, who was assisted by Mr. Bearse. During 1939 the fishing vessels landed 376,000,000 pounds of groundfish at Boston, Gloucester, and Portland. Compared with 1938, when 379,000,000 pounds were landed, this represents a decrease of less than 1 percent. However, the value to the fishermen rose from \$8,352,000 in 1938 to \$9,017,000 in 1939; an increase of 8 percent.

An outstanding feature of the 1939 fishery was the continuing expansion of the rosefish catch. In 1933 the catch was less than 300,000 pounds, and in 1934 it was just under 2,000,000 pounds. In 1935 the filleting of rosefish gave the product access to the markets of the Midwest—where they are sold as “ocean perch”—and the catch rose to 17,000,000 pounds. In 1936 it jumped to over 66,000,000 pounds, which was almost too large for the market to absorb. In 1937 the catch fell off to 58,000,000; in 1938 it was 65,000,000 pounds; and in 1939 was 77,600,000 pounds.

During 1939 the large otter trawlers, which have a long cruising radius, commenced taking large quantities of rosefish off eastern Nova Scotia, especially in The Gully, just south of Banquereau. From July to December 1939, this area accounted for over 8,400,000 pounds, or 58 percent, of the rosefish catch of the large trawlers, whereas it accounted for only about 1 percent of their catch during like periods in 1937 and 1938.

The various species of groundfish form the basis of the most important New England fisheries. Although it has been known that the total yield has fluctuated, our knowledge has been too limited to know the causes, or which species are most affected. The shift in the fishery within the past few years toward rosefish and grey sole, for instance, presents the problem of discovering what effect these changes are having on the species that were already being intensively exploited. Indices of abundance are being determined for each species, which are so constructed that they may be added to from month to month to show any sudden changes. Under a system which made only irregular summaries of abundance those changes might be unnoticed for a long period. When the indices are completed, however, it will be possible, as soon as the requisite knowledge of the life history becomes available for each species, to suggest means of maintaining the population at that level which will yield the largest sustained annual catch.

The study of the three variables—total catch, fishing effort, and abundance—is difficult in a fishery that covers such a wide geographical area. At times the fleet operates in comparatively shallow water, and at other times in deep water, and the species taken vary accordingly. Also, some species are more available to the fishermen at certain seasons than in others, so that only comparable seasons yield valid comparisons. Since the welfare of thousands of New England fishermen, shore workers, and fillet cutters depends on the maintenance of this tremendous fishery, it is essential that we understand the factors responsible for changes in yield. Not only can that knowledge help to prevent a decline similar to that suffered by the North Sea fisheries, but it can also deter the enactment of irresponsible legislation which is sometimes a “stop-gap” not based on complete knowledge of the facts.

Statistics.—The first step in assessing the condition of this fishery is to obtain information on the yield. Since even the same species may have independent stocks on different banks, it is necessary to know the quantities caught in each area. This information is obtained for all boats of over 5 net tons landing at Boston, Gloucester, or Portland, and is published monthly by the Division of Fishery Industries. It also gives an excellent summary showing the type of gear used and the bank where caught. The landings at these three principal ports comprise about 65 percent of the New England landings, and all but a small fraction of the offshore catch. The information on fishing banks was brought up to date in 1939 by making several slight changes in the boundaries of statistical subareas based on the grounds fished by large otter trawlers in 39,632 days of fishing from 1928 to 1937, inclusive. A 1-year trial of the new boundaries has shown that they conform more closely with the natural fishing areas than those previously adopted.

Until 1939 the only available records of the total New England catch have been those of the Bureau's annual canvass. However, due to limited personnel and funds, this canvass cannot achieve the desired degree of accuracy, since it is made only once a year at the end of the season and many of the fishermen from whom records are obtained do not keep accurate accounts. Furthermore, such annual statistics do not show the season or the locality of the catch.

In cooperation with the Division of Fishery Industries, the North Atlantic staff has encouraged the installation of adequate statistical systems by the New England States. The State of Maine installed a system on Jan. 1, 1939, whereby the dealers use triplicate receipt books, furnished by the State, for each purchase of fish. The State collects one copy of each transaction at the end of each month. The State of Connecticut commenced a similar system during the year. The Market News Service of the Bureau now obtains information on all landings at Provincetown and New Bedford, Mass. Although there is still much work to be done, the progress made during 1939 will assure the most complete statistics so far obtained on the New England fisheries.

Fishing effort.—The amount of fishing effort expended in relation to the volume of the annual catch is of great importance in studying the trend of a fishery. The changes in type of gear and in the size and style of fishing boats should also be known. Such information

provides a perspective for analyzing the state of a fishery. The catch, tabulated according to vessel and size and type of gear, is being compiled from the reports of landings at the three principal New England ports. Data have been assembled for all except 2 years of the 1927-39 period.

A comparison has been made between the catches of 1927 and 1938. During 1927 the average number of vessels that landed each month was 218 (including a total of 364 boats). The average was computed on a 12-month basis so that in the purse-seine fishery, for example, if 60 boats fished 6 months the average for the entire year would be 30 boats. If a boat used two types of gear during the same month, each gear has been credited with half a month. The average number of boats that landed catches each month during 1938 was exactly the same, 218 (332 different boats landed). Not only was the same number of landings made in 1927 and 1938, but the average gross tonnage per individual boat was 96 in each year.

However, there was a 50 percent increase in the landings of all species, from 268,000,000 pounds in 1927 to 401,000,000 pounds in 1938. This appears to have been due largely to a radical change in the proportions of each type of gear used. All forms of gear except otter trawls and sink gill nets decreased in numbers. Hand-lining accounted for an average of 10 boats fishing throughout 1927, but that method of fishing had practically disappeared in 1938. The average number of purse seiners decreased from 35 to 20. The line trawlers decreased 34 percent in number and 52 percent in gross tonnage. This apparent discrepancy is accounted for by a decrease from 49 to 23 in the line trawlers of over 50 gross tons, but an increase from 8 to 15 in the average number of smaller line trawlers. The number of otter trawlers increased 60 percent, from 76 to 121, due largely to the building of new boats, although, to a lesser extent, it was also due to the present practice of operating a boat throughout the year. In addition, several line trawlers were converted for otter trawling. The medium-sized otter trawlers in operation, 51 to 150 gross tons, increased from 22 to 34, or 55 percent; the large, from 24 to 40, or 67 percent; and the small otter trawlers from 30 to 47, or 57 percent. Thus, the large trawlers showed the greatest increase in numbers. In 1927, with an average of 24 large trawlers in operation, 88 percent were propelled by steam. In 1938 steam accounted for only 24 percent of an average of 40 large trawlers, the balance being Diesel-powered.

Other factors in addition to the shifts in type of gear contributed to the 50 percent increase in landings. One was the adoption by the otter trawlers of the Vigneron-Dahl trawl, which increased their catches considerably. A second factor is the newly developed fishery for rosefish, which produces a greater poundage per unit of effort than any other species.

Population estimates.—Having laid the ground work for the determination of total catch by season and area, and of total fishing effort, there remains the third variable—abundance.

Very fortunately the haddock investigations, as one phase of their activity, commenced collecting data at the Boston Fish Pier in 1932 that are of great value to the groundfish analysis. The phase of the haddock work dealing with abundance will henceforth be carried on

as a part of the determination of abundance of all species of ground-fish.

At the Boston Fish Pier the captains of all vessels of over 50 gross tons are interviewed at the end of each trip. The data listed includes the day and hour of departure and arrival at the pier; the fishing locations by rectangles covering 10 minutes of latitude and of longitude; the depth fished; the number of hours of fishing time lost through bad weather, engine trouble, or other causes; the proportion of time spent on each bank; and the proportion of the trip (and of most of the species caught) on each bank. For line-trawl vessels the number of tubs of gear set on each bank and in each depth also is obtained. These interviews are now being made by Mr. Bearse. During 1939 the catches were allocated to their appropriate subarea and depth zone, and the fishing time for selected groups of otter-trawl vessels was calculated. The calculated number of fishing days and catch allocations were added to the punch cards used by the Division of Fishery Industries in tabulating the material for its monthly bulletin on the landings at the three principal New England ports according to fishing bank and type of gear. As soon as the indices of abundance by species for the 1932-38 period are completed it will be possible to follow the changes in abundance from month to month.

For the two selected groups of large otter trawlers, the catch and number of days of fishing in each statistical subarea during each month has been tabulated, according to depths fished, for the period 1932-38, inclusive. One group of trawlers is slightly over 90 percent as efficient in fishing ability as the other group. By making an allowance in the number of fishing days, it is possible to place the two groups on an equal basis and to combine the data for final analysis.

The determination of abundance is further complicated, however, by the necessity of analyzing the data according to the depths fished, inasmuch as different species vary in their choice of habitat. Accordingly, all catches have been allocated to 3 depth zones, namely: Shallow, 0 to 30 fathoms; medium, 31 to 60 fathoms; and deep, over 60 fathoms.

The analysis of trips for area XXII—the banks of the Gulf of Maine, Georges Bank, and Nantucket Shoals—in which the otter trawlers fished wholly within 1 depth zone and 1 statistical subarea, show that although most species vary considerably in abundance in the different depth zones, this is not true for haddock. Giving each depth zone an equal weight, the relative abundance of large haddock on the basis of 100 percent was 35 for shallow water and 32 for both medium and deep water. Scrod haddock had a relative abundance of 37 for shallow, 40 for medium, and 23 for deep water. This may be an artifact, because, since haddock represent over 60 percent of the catch, the fishermen are seeking locations where they are most abundant and fish each depth most intensively at the time when haddock are most abundant there.

The flounder group—blackbacks, lemon sole, and yellowtail—definitely prefer shallow water, and yielded percentages of 88, 72, and 76, respectively, as compared to 11, 23, and 20 for medium depths, and only 1, 5, and 3 percent for deep water. Grey sole and dabs, on the other hand, are deep-water species; 84 and 69 percent coming from over 60 fathoms. Cusk, pollock, and hake are all taken in much

greater quantities in deep than in shallow water. Almost 100 percent of the rosefish are likewise from the deep zone.

As soon as the data can be analyzed for seasonal abundance, and for varying degrees of abundance according to geographical location, the final curves of annual changes in abundance will be determined. For a few species, such as cusk and hake, which are taken only in small quantities by the otter trawlers but in large quantities by hook and line, we may have to depend largely on the analysis of the catches of line-trawl vessels. Data showing the number of tubs of gear fished by selected line trawlers and their catch for each depth and subarea have already been assembled for 6 of the 7 years under consideration, and will be analyzed in a like manner.

LOBSTER

The lobster fishery is of paramount importance to the shore fisheries of the North Atlantic States, since it furnishes all or part of the income of great numbers of small-boat fishermen from Maine to New Jersey. In 1937 this fishery produced a catch of over 11,500,000 pounds, worth nearly \$2,500,000. Fifty years ago the catch was nearly three times as great, but it has declined in spite of protective regulations in all States, and artificial rearing in some.

The research program began in March 1939, with the employment of Leslie W. Scattergood to carry on the investigations. The program has been divided into two main parts—the first dealing with hatchery and rearing methods and the second with the study of the Maine lobster population to obtain biological data necessary for the most effective management of the fishery.

More than one-half of the total catch is accounted for by the Maine fishery. The records collected by the Maine Department of Sea and Shore Fisheries showed the catch in 1939 to be 6,625,000 pounds, compared to about 23,000,000 pounds 50 years previously when the fishery was much less intensive. Because of the importance of this species to the fishermen, and the need for the adoption of measures to attempt to maintain the yield, the State of Maine constructed a large rearing station at Boothbay Harbor in 1938 and 1939, and in the latter year joined in a cooperative lobster-research program with the Bureau of Fisheries. The object of the investigations undertaken was to develop improved methods of rearing lobsters and to obtain data that would assist in the determination and establishment of an adequate minimum-size limit.

Experimental rearing to the fourth stage was conducted at the hatchery under different conditions of temperature, light, and food, but, due to unnatural water conditions present in the rearing station, the work was beset with difficulties which were only partially overcome at the end of the rearing season. Further experimental rearing, under more suitable conditions, will be attempted during the spring and summer of 1940.

The commercial catch of lobsters was sampled along the entire coast of Maine from Cape Porpoise to Cutler. The sex and carapace length, as defined by State laws, were recorded for over 15,000 lobsters. From these samples it was found that 12 percent of the number had a carapace length of less than $3\frac{1}{8}$ inches, 34 percent under $3\frac{1}{4}$ inches, and but 8 percent above $3\frac{3}{4}$ inches. Measurements

of seed lobsters taken along the Maine coast indicate that they do not mature before they reach a length of $3\frac{3}{4}$ inches; in many regions we have reason to believe that sexual maturity must be first reached at a length greater than $3\frac{3}{4}$ inches. It appears that only about 8 percent of the population has an opportunity to spawn. Further research must be carried on concerning this problem.

As a result of a request from the North Atlantic Lobster Committee to "assemble information concerning size limits and begin the research work required to obtain additional biological information necessary for sound recommendations concerning size limits," certain data were gathered during the summer and fall fishing season. These observations consisted of a determination of the size composition and sex ratio of the commercial catch, length-weight relationships, the relationship between the length measurements from eye socket to end of the carapace and total length measured from the tip of the rostrum to the end of the tail, and size measurements of seed lobsters. As seed lobsters proved to be difficult to find in any numbers during the summer and fall, an indirect method of determining the sexual maturity was employed which was based on the fact that the width of the female's abdomen increases at a higher rate than body length with the approach of sexual maturity.

The present size regulation of $3\frac{1}{16}$ inches, carapace measurement, allows the capture of small, immature lobsters which results in an economic as well as a biological waste. A $3\frac{1}{4}$ -inch lobster weighs 1 pound, on the average. The important summer and fall fishery depends upon lobsters under 1 pound for 34 percent of its numbers. These small "chicken" lobsters are not in demand on the markets and a general lowering of the prices occurs with the overabundance of undesired sizes.

Tagging experiments were carried on to determine the interdependence of local populations and to measure the intensity of the fishery. A total of 413 lobsters were liberated in three groups in Boothbay Harbor; one lot in July, another in August, and a third in November. The recoveries were 27, 55, and 31 percent, respectively. The first percentage recovery is not comparable to the second and third, as the lobsters of that group were near the shedding stage, at which time they would lose the tags. One hundred lobsters were released in the Sheepscot River, a long tidal estuary, during October and a 7-percent recovery resulted by the end of December. On the offshore fishing grounds of Sheepscot Bay, 186 lobsters were liberated in July and 100 in December. Recoveries of 12 and 3 percent, respectively, were made by the end of the year.

It is too early for the final results of the tagging to be known, as more tagged lobsters are expected to be caught during the summer and spring of 1940. At the present time, the longest migration has been $3\frac{1}{2}$ miles, and two facts are evident from the tag returns: First, there is very little migration during the summer and fall months; and, second, the intensity of the fishery may vary in different regions, depending upon the season and the number of traps fished in an area.

Although records of daily catches and the number of lobster traps fished by the entire industry are not available for the year, certain lobster dealers have kept daily records of the catches of their fish-

ermen, thus providing a means of sampling the poundage yield per trap unit.

MIDDLE AND SOUTH ATLANTIC FISHERY INVESTIGATIONS

ROBERT A. NESBIT, *in charge*

A few years ago it would have been correct to state that the principal objectives of conservation administration in the Middle and South Atlantic region are: To protect the interests of the consuming public in an abundant production of food fish and to promote the welfare of the commercial fishermen. Today, however, it is necessary to add a third objective—to protect the interests of salt-water anglers. The number of anglers has increased greatly in recent years and many active organizations which are very influential in matters of conservation legislation and administration have been formed.

It has often been pointed out that the interests of the consuming public, the commercial fishermen, and the anglers are identical in that they are best served by the maintenance of high levels of abundance. Also it has frequently been indicated that the only controllable influence on abundance is the fishery itself, and that the only effective means of exercising control is by management of the intensity of the fishery.

That it makes a great deal of difference how the intensity of an excessive fishery is reduced is a point that is repeatedly overlooked. Complete elimination of commercial fishing would protect the interests of anglers, but obviously would be contrary to the interests of the consuming public and the commercial fishermen. Measures designed to reduce excessive fishing by requiring commercial fishermen to use inefficient methods, that is, by making it unprofitable to fish excessively, protect the interests of the public and the anglers but are unsatisfactory to commercial fishermen.

It is apparent, therefore, that if effective cooperation of all interested groups is to be obtained it will be necessary not merely to eliminate overfishing but also to eliminate it by some means which will not only protect the fish but will also protect the profits of commercial fishermen.

Since the cost of fishing is almost directly proportional to the amount of gear operated, the most economical method of decreasing fishing intensity is to reduce the amount of gear employed to a minimum. Recent recommendations by the Middle Atlantic staff, based on this principle, have been received favorably by commercial fishermen in Chesapeake Bay. It is possible, therefore, that such proposals will provide a basis for better cooperation between anglers and commercial fishermen.

As in previous years, office and laboratory space was provided by the University of Maryland. In the conduct of these studies much voluntary cooperation has been received from the conservation departments of several States and from organizations of commercial fishermen, sports fishermen, and dealers. Special thanks are extended to the conservation departments of Rhode Island, Connecticut, New York, New Jersey, Maryland, Virginia, North Carolina, and South Carolina. The staff also profited greatly by the cooperation of the

Narragansett Biological Laboratory and its director, Dr. Charles J. Fish, and the Chesapeake Biological Laboratory and its director, Dr. R. V. Truitt.

SHORE FISHES

Investigation of the shore fishes of the Middle Atlantic region during 1939 was continued by William C. Neville. The work included a study of fishery problems in Long Island, N. Y., conducted in cooperation with Suffolk County (reported on pp. 27-29 of this publication), and observations on the winter trawl fishery off the Virginia Capes.

Winter trawl fishery.—The year 1939 marked the eighth anniversary of the winter trawl fishery off the Virginia Capes. The establishment of this activity as a permanent part of the industry is indicated by continued large annual production. Approximately 18,000,000 pounds of fish were landed at the principal ports in Virginia, New Jersey, and New York during the 1939 season. This high level of catch has been maintained during the past several years. The most pressing need in the study of the probable effect of the winter fishery on the general supply of sea bass, scup, fluke, and croakers, which species comprise the major part of the catch, is to devise saving methods to release undesirable market sizes of fish, in good condition, at sea. It is hoped that such savings work can be started in the near future through the use of the trawler recently acquired by the Bureau and now being remodeled and equipped at Boston.

ANADROMOUS FISHES

Striped bass.—The principal objectives of the striped bass study conducted by William C. Neville in 1939 were: (1) Continuation of the studies which led to the Bureau's recommendation of a minimum size limit of 16 inches, measured from the snout to the fork of the tail (approximately 17½ inches overall), as the best means of securing greater yields and larger profits from each brood of striped bass, regardless of its relative abundance. (2) To determine the extent to which the available supply in the various States depends on local reproduction, or on migrations of fish from other parts of the coast, and whether, on the basis of the source of the supply and the extent of withdrawal by the fishery, more restrictive or protective legislation is necessary for the proper utilization of the supply.

Mainly as a result of the Bureau's recommendation, the legal limit of striped bass was raised to 16 inches, fork length, in New York State during 1939. A slightly higher size limit is in effect in New Jersey. Recommendations for substantial increases in the legal size limit for striped bass have been submitted to the fishermen by the Virginia Commission of Fisheries, and similar action is expected in Maryland and North Carolina. These three States comprise the most important striped bass production area along the entire Atlantic coast. Analysis of biological data obtained through tagging experiments reveals that the fishery is so intensive in certain parts of Chesapeake Bay as to remove a considerable quantity of the small sizes of bass. Hence, it is particularly important that Virginia and

Maryland increase their size limit to the Bureau's recommendation of 16 inches to insure more efficient utilization of the supply. The increased size limit will result in a greater total catch and value, provided by an equal number of fish of the same year class.

A survey of the coastal regions of Chesapeake Bay to southern New England during 1939 confirmed conclusions resulting from previous study that not all important areas for striped bass furnish their quota of young to replace the larger-sized fish removed by the fishery. Spawning grounds of significant importance were located in the Maryland waters of Chesapeake Bay, Delaware Bay, and the lower Hudson River in New York. According to studies made in previous years, the lower Chesapeake Bay and the sounds and coastal rivers of North Carolina are also productive areas. Results of the survey in 1939 indicated a notable lack of successful reproduction of striped bass along the ocean coasts of New Jersey, Long Island, and southern New England. These observations suggest that the adult stock in these latter regions originates mainly from the migration of young fish from the more productive spawning and nursery areas of Chesapeake Bay, and possibly Delaware Bay and the Hudson River.

The survey also revealed that spawning in 1938 and 1939 in the important Chesapeake Bay region was relatively unsuccessful, despite the fact that the spawning stock was one of the largest on record. This was in marked contrast to the unusually successful reproduction that occurred in 1934, when the stock of adult fish was relatively low. This disclosure supports the results of previous studies in that the production and survival of young striped bass are, to a large extent, independent of the number of spawners, and hence regulatory measures to increase the spawning stock are not of primary importance in the proper conservation of the species. The Bureau's recommendation of a 16-inch size limit will, however, increase the number of spawners, but it is intended more specifically to insure better utilization of each brood. Results of the study of spawning and nursery areas for striped bass, and of tagging experiments to determine the extent of the withdrawal on the stock and additional information on the seasonal migratory habits of the species, have been considered in connection with the question of whether more restrictive legislation intended to improve or maintain the abundance of striped bass is necessary in some of our Atlantic Coast States.

Shad.—Further study in 1939 confirmed the opinions expressed in the report for 1938 to the effect that the principal cause of depletion is overfishing, rather than pollution or obstruction of runs, and that recovery can best be brought about by providing a spawning escapement substantially equivalent to that which has proved adequate in the Hudson River.

Study in 1939 also brought out the important point that the moderate fishing rate in the Hudson eventually takes as much shad from each year class as the more intensive fishery in Chesapeake Bay, but spreading the catch over several years allows six times as much spawning from each year class.

In December 1939, a memorandum was submitted to the conservation departments of Maryland, Virginia, and North Carolina, sum-

marizing the results of the shad studies in 1938 and 1939 and making recommendations as follows:

For the restoration of the shad fishery of Maryland, Virginia, and North Carolina, then, the Bureau recognizes the following fundamental facts and principles: (1) The decline in shad production in Maryland, Virginia, and North Carolina is the result of overfishing. (2) To correct overfishing of shad the annual toll taken by the fishery should be reduced to 60 percent of the present rate. (3) This should be accomplished by restricting the amount of gear operated so that the fishermen will be spared the uneconomic practice of purchasing and operating more gear than is required to take the annual harvest.

In accordance with these principles it is specifically recommended: (1) That appropriate steps be taken by the States to secure necessary additional detailed information as to the amount, the location, the period of operation, and the catch of existing gear in order to accomplish equitably this reduction in fishing gear; (2) that when sufficient detailed information is available appropriate legislation be enacted to accomplish the reduction in gear on a trial basis and to modify such regulations as experience accumulates; and (3) that no expenditures be made for enlarging permanent hatchery facilities and that existing hatcheries be operated strictly on a salvage basis until natural reproduction has been restored.

Investigations of the early life history of the shad were made at the Charleston (S. C.) Office by Louella E. Cable. Because the survival of eggs and young of shad will determine the number of spawning fish required to maintain or build up any given population, studies were designed to determine the survival rates. A survey of the Edisto River, and preliminary plankton collections in 1938, revealed the best spawning areas of the river and provided material from which it was learned that large numbers of eggs are not fertilized and that the survival rate may be as low as 1 percent.

Two stations, one at the upper limit of the spawning area and the other near its center, were sampled intensively during the 1939 shad season for evidence of a possible differential in survival rate, but none was noted. With slight variations, findings of the previous year were substantiated. In 1940 the same central station will be sampled as in 1939 and two lower stations will be added, one to be located in brackish water.

The shad population of the Hudson River, N. Y., has shown, within the past few years, a phenomenal increase as reflected in the commercial catch. Does this indicate a higher survival rate of the eggs and young in the Hudson than has been found in the Edisto River, or is the increase entirely due to a larger escapement of spawners? To better understand the change, it is planned to work on the Hudson in the near future.

Racial studies based on meristic characters, made by Miss Cable, indicate the existence of several populations of shad along the Atlantic coast. These studies will go far in corroborating evidence obtained from tagging experiments and scale readings.

FISHERIES OF SOUTH CAROLINA

Fishery research at the Charleston office, which is in charge of John C. Pearson, concentrated upon fundamental studies of the distribution and abundance of the eggs and young of the shad in Southern coastal rivers, particularly the Edisto River. Several secondary fields of research also present themselves to the trained fishery observer as worthy of investigation. Such research may properly be conducted with the present facilities at Charleston.

It is a matter of general knowledge that the largest hydroelectric development in the Southeastern States, the Santee-Cooper project, is now under way. It is proposed to divert at least one-half of the normal flow of the Santee River over a series of dams into the headwaters of the Cooper River, a tributary of Charleston Harbor. Although the Santee River system is not important from a fishery standpoint, important and perhaps far-reaching ecological changes will take place not only in the lower regions of the Santee but also in the Cooper River. So far, little has been said of the effects of the diversion with respect to the Cooper River, although the U. S. Bureau of Biological Survey realizes the effects of the project on the wildlife, particularly ducks, of the lower Santee River.

The Cooper River, a relatively new and large coastal river created by man, now largely of estuarine character and possessing salt or brackish water, will become fresher with the incursion of fresh water from the Santee River. Aside from becoming a problem of immense interest from a strictly ecological standpoint, probably the most striking change effected by man on an estuarine environment, certain features of practical consideration come to mind. The most valuable aquatic resource in South Carolina is the marine shrimp, *Penaeus*, and nearly 2 million pounds of this crustacean are taken annually in coastal waters of that State. Research has indicated that estuarine areas along the coast are essential nursery grounds for young shrimp after they have been spawned at sea and are carried into shallow in-shore estuaries. The young shrimp require salt or brackish water in a shallow, muddy environment for adequate survival and growth. The estuarine area of the Cooper River provides one of the important shrimp nurseries along the South Atlantic coast. Its contribution to the supply of shrimp in this region may be considerable because millions of shrimp utilize this area for growth, shelter, and development.

The investigative problem is to determine the effect of the constant influx of fresh water upon the environment, especially the nursery areas. Obviously, the salinity of the brackish areas will be reduced, and it is important to know whether this will cause any decrease in the annual catch of shrimp along the coast.

Another secondary problem which could be pursued within the field of fishery biology at Charleston concerns the fishery for sea bass or blackfish. The latter are taken locally on coral reefs off the coast and are probably independent populations from those of more northern areas. The fish are captured solely by hook and line and comprise the third most valuable fishery within the State.

A study of the size and age composition of the catch, correlated with the location of the catch, might throw light on one basic point in modern fishery biology, e. g., does overfishing occur on some reefs, as might be indicated by a lower size and age composition of the fish population, when accompanied by a decrease in catch per unit of effort? Studies of the sea bass stocks to determine such fundamental facts might prove profitable.

SUFFOLK COUNTY COOPERATIVE INVESTIGATION

WILLIAM C. NEVILLE, *in charge*

During the year 1938 a survey of the marine fisheries of Long Island waters was conducted by the New York Conservation Depart-

ment, assisted by the Bureau. Public interest aroused by that survey led to an appropriation of \$6,750 by the Board of Supervisors of Suffolk County, N. Y., for a study in cooperation with the Bureau, of the local fishery problems of that county. The investigation, planned to continue until June 1940, was under the joint supervision of William C. Herrington and Robert A. Nesbit and directed by William C. Neville, of the Middle Atlantic staff. He was assisted by Milton J. Lobell, of the North Atlantic staff, who continued the flounder studies until September 1939, when he was transferred to the U. S. Department of the Interior Antarctic Expedition. Alfred Perlmutter, who was appointed to the North Atlantic staff in December 1939, resumed the flounder investigation.

The studies undertaken will be of value not only to the county but elsewhere in the middle Atlantic region where similar problems occur. The main objectives of the study are as follows:

1. To determine whether any serious decline in the abundance of winter flounders is occurring, and what remedial measures are desirable to maintain a high level of abundance or to insure the best use of the local supply. In this study attempts are being made to determine the effectiveness of planting hatchery-reared fry in an effort to increase or maintain good catches; the desirability of increasing the legal size limit from 6 to 10 inches, and whether current fishing practices result in any great mortality of illegal or unmarketable sizes of fish that are discarded at sea.

2. To determine whether an increase in the size limit on weakfish from 9 to 12 inches would improve the catches of larger-sized fish of greater market and recreational value.

3. To seek practical saving methods to curtail the destruction and waste of illegal and undesirable market sizes of fish.

Favorable progress has been made on all three main objectives. In the winter-flounder study, information collected during 1937 and 1938, supplemented by data in 1939, indicates that different regions of Suffolk County have independent population units, so that efforts to improve fishing conditions can be applied directly to individual areas. Marked differences in the rate of growth of flounders occur in these separated regions, thus permitting determination of the probable benefits to each region through increases in the legal size limit. Frequent contacts during the past 2 years with commercial and sport fishermen of Suffolk County have resulted in much personal interest in the study, and through individual cooperation accurate catch-record data are expected to be available for determining the extent of fluctuations in amount of catch.

The question of whether benefits can be derived by increasing the size limit of weakfish from 9 to 12 inches can be answered in part on the basis of results of the Bureau's study of this species since 1928, and of the biological survey of Long Island made in cooperation with the New York Conservation Department in 1938. Releasing weakfish less than 12 inches in length in New York waters would result in at least some of these fish returning to New York waters as larger-sized weakfish. It is still uncertain, however, whether the gains would fully compensate for the losses. Weakfish are delicate and many would not survive sorting by hand. Progress has been made in adapting the "sifter" method long used by Rhode Island trap oper-

ators, not only to small weakfish but to butterfish as well. As much as 80 percent of the smaller sizes can be released by sifters of appropriate mesh more quickly than by hand sorting, and with less mortality. Unfortunately, this method is not applicable at all seasons, for at times the runs are made up of several species so that sifters of appropriate mesh for one species will permit the escape of marketable sizes of other species or will cause objectionable gilling. Results of these studies will be included in a report to be submitted to the Board of Supervisors of Suffolk County by July 1, 1940.

SHRIMP INVESTIGATIONS

MILTON J. LINDNER, *in charge*

During the past several years the shrimp fishery has been characterized by the rapid expansion of the market for the "fresh-headless" product. This industry first came into prominence along the Atlantic coast in the early thirties. With the initiation, in the winter of 1937-38, of an offshore fishery in Louisiana for the large-sized shrimp, generally known as "jumbo," this phase of the shrimp industry has now become of considerable importance in the Gulf of Mexico. The rapid rise in the fresh-headless shrimp business, together with a growing demand for canned shrimp, has led to considerable increase in fishing effort. The augmentation of fishing, due to the increase in the number of boats, size of craft, and the efficiency of their operation, has placed a strain on the supply of shrimp along the Atlantic coast. The greatly increased fishing intensity has not resulted in an appreciable increase in the catch, but, on the contrary, it has resulted in a decrease in the catch of the individual fisherman with respect to the amount of effort expended. In Florida the increased intensity has resulted in a lesser total catch during the winter fishery, which is composed of migrants from North Carolina, South Carolina, Georgia, and northern Florida. Apparently the fishery on the Atlantic coast is so heavily prosecuted that a great proportion of the migrant shrimp are captured by the fishermen before they reach their wintering ground between St. Augustine and Cape Canaveral, Fla.

Extreme competition, together with the discovery of jumbo shrimp off the Louisiana coast, has led a number of Atlantic coast shrimp boats to migrate to Louisiana to enter the offshore fishery. The Atlantic coast shrimp vessel is much better suited for the offshore work than is the Gulf-style shrimp boat which has been developed for use in the shallow inland bays and bays.

During 1939, as in previous years, the shrimp investigators were furnished office quarters by the Louisiana Department of Conservation, at New Orleans. The city of Gulfport, Miss., supplied dockage and storage space for the *Pelican* and its gear. Due to the curtailment of funds it was necessary, in February, to temporarily suspend the Texas investigations which were being conducted in cooperation with the Texas Game, Fish, and Oyster Commission. For the same reason the tagging operations with *Launch 58* and the exploratory work with the *Pelican* were interrupted during February and March, respectively. Both boats were again placed in commission after

July; the *Pelican* for a brief period during August and *Launch 58* continuously, for tagging purposes.

Through the cooperation of Dr. R. Dana Russell, School of Geology, Louisiana State University, the bottom-core and mud samples collected with the *Pelican* are being examined. In addition to an analysis of the chemical and physical characteristics of the bottom deposits by Dr. Russell, the Foraminifera, Bryozoa, and Ostracoda will be identified by Drs. Howe and McGuirt of the School of Geology. Through Dr. H. N. Fisk, Louisiana State University, the mollusc collections are being identified. The salinity samples are being analyzed by Professor Albert E. Parr, of the Bingham Oceanographic Institute.

With the interruption of the Texas work, field operations have been restricted to exploratory work with the *Pelican* in the offshore waters of the Gulf and tagging experiments with *Launch 58*. M. J. Lindner and W. W. Anderson conducted the studies made with the *Pelican* and Albert Collier of the Texas Game, Fish, and Oyster Commission assisted during the Texas cruise. C. H. Baltzo has been conducting the Gulf tagging experiments. From June 17 to December 9 Mr. Lindner was detailed to Mexico to assist the Mexican Government in some of their fishery problems.

Messrs. Lindner and Anderson examined and identified the entire collection of penaeid shrimps collected with the *Pelican* in the Gulf of Mexico. This collection contained 16 species of Penaeidae, only 4 of which ever enter the commercial fishery. One, the common shrimp (*Penaeus setiferus*), comprises at least 95 percent of the commercial catch, and all discussion in this report refers to that species.

Information of considerable value was made available during 1939 by the publication entitled, "The early life histories of some American Penaeidae, chiefly the commercial shrimp *Penaeus setiferus* (Linn.)", by John C. Pearson.

OFFSHORE OPERATIONS

Because of the constantly increasing drain on the shrimp population it is particularly important to know whether or not there is a reserve supply of shrimp available beyond the range of the present commercial fishery. The recently developed fishery off the Louisiana coast is a direct result of the studies carried on by these investigations. The possible discovery of additional and similar concentration areas will prove of immediate economic importance to the industry. If such additional areas do not exist it is of both biological and economic significance to know this fact. Future expansion of this fishery will depend appreciably on the presence or absence of additional virgin fishing grounds, and no well-founded management can be attempted without complete knowledge pertaining to the distribution of the shrimp and the limits of its range. The possibility of an offshore spawning reserve can be determined only by fishing in depths greater than those now exploited by the fishing boats.

In an attempt to solve these problems the *Pelican* was used between January 14 and March 15, 1939, to explore the area between the beach

and the 100-fathom contour from the Mexican border to Carrabelle, Fla. Throughout this stretch of bottom 380 hauls, of one-half hour duration each, were made with a 9-foot otter trawl. The trawl actually was dragged over 1,200 miles of ocean floor. In addition to trawling, the *Pelican* occupied 70 hydrographic stations at which 158 salinity samples, 51 Petersen dredge samples, 51 mud samples, and 20 bottom-core samples were taken, together with temperature observations at each station.

Again, as in 1938, concentrations of large shrimp were found off the central Louisiana coast near the 10-fathom line between Ship and Trinity Shoals. No comparable aggregations were found along the entire length of the Texas coast. East of the Mississippi River, between Mobile, Ala., and Carrabelle, Fla., the catch was even less than along the Texas coast. At no time were common shrimp taken in depths greater than 15 fathoms.

These results indicate that the common shrimp does not go to any great depths; that the shrimp boats working in the offshore Louisiana area extend their fishing operations to the outer limit of the range of the common shrimp; that there appears to be little likelihood of other offshore fishing areas being developed in the Gulf with a magnitude comparable to that now present between Ship and Trinity Shoals; and that bottoms composed primarily of sand, shell, or coral do not provide a suitable habitat for the shrimp.

Since it has been determined that the common shrimp does not inhabit areas in the Gulf of Mexico that are outside of the range of operations of *Launch 58*, it was decided that further work with the *Pelican* would be unnecessary in the Gulf. However, similar offshore studies on the distribution of shrimp along the Atlantic coast also are needed, for the same reasons that they were required in the Gulf. The *Pelican* will be transferred to the East coast in January 1940, for the purpose of performing exploratory trawling out to the 100-fathom contour between Fort Pierce, Fla., and Cape Hatteras, N. C. When this exploratory work has been accomplished we will be in a position to recommend what, in our judgment, appears to be the best method for the management of the Atlantic coast shrimp fishery.

MIGRATION STUDIES

As shown by tagging experiments, the Florida winter fishery is comprised of migrants from as far north as North Carolina. Before the migrating shrimp can reach their Florida winter ground they first must run the gamut of the fishery along the entire stretch of coast from their nursery ground to their winter ground. The fishing intensity has been so severe during the past few years that only a small portion of the shrimp that start out on this migration ever reach their objective.

Since the shrimp definitely is migratory, the solution of the Atlantic coast problem lies not within the individual responsibility of any one State but must be the accomplishment of unified action on the part of all four of the States involved. Until the current year, although suspected, it was not known whether similar united action would be advisable in the Gulf of Mexico in case the need arose. However, tagging experiments conducted in Louisiana, Mississippi,

and Alabama, during 1939, have shown that the shrimp populations in these three States move from one State to another. Here, again, we have the necessity for two or more States to unite in their efforts to properly regulate a migratory fishery.

Inasmuch as the common shrimp does not possess any of those structures common to many fishes and molluscs by means of which the age of an individual specimen can be determined; and inasmuch as the shrimp apparently has a relatively short life span, an extended spawning season, a complex migratory nature, and the habitat changes markedly during its life span, many problems concerning its life and habits can be solved only by means of tagging. The problem of growth is complicated at certain periods of the year by local movements, migrations, an extended spawning season, and the lack of dominant size classes. The problem of fishing intensity has presented innumerable difficulties due to the lack of adequate catch statistics in all of the shrimp-producing States. This problem has been complicated further by the migratory nature of the shrimp and the fishing boats. Tagging experiments are the most feasible approach, so far devised, to the problems of growth, migration, longevity, and fishing intensity. Tagging constitutes a technique that has proven successful in tracing migrations of the South Atlantic shrimp and in providing information on the other questions. All of these problems require solution before a well-founded management of the fishery can be proposed.

Because of extensive offshore fishing and the migratory nature of the shrimp, tagging experiments were first conducted along the Atlantic coast. Now, however, with the establishment of an offshore fishery in the Ship and Trinity Shoals area off central Louisiana, a means is provided for securing the return of tags throughout the year. During the last few weeks of 1938 the ground work was laid for a series of shrimp-tagging experiments in Louisiana waters. Fishermen and dealers throughout the experimental area first were made acquainted with the nature of the investigations to be performed, by means of newspaper articles, talks, and posters. The willing assistance and genuine interest of the industry have contributed to the success of the entire program. The fishermen cooperated by returning captured tagged shrimp and reporting where and when they were taken, and the dealers preserved and retained the specimens and data on their premises until the Bureau's agent could collect them.

The tagging program commenced during mid-December of 1938, when 2,300 shrimp were released in 3 localities between the Mississippi and the Atchafalaya Rivers. During the following month 1,750 additional tagged shrimp were released in the Ship Shoal area. Although these initial plants of approximately 4,000 shrimp were to have been succeeded by regular monthly releases, an unforeseen shortage of funds forced the temporary cessation of the work until the following summer. Tagging was resumed in late August 1939 and continued uninterruptedly for the remainder of the year, and 12,200 shrimp were released during the period. At the same time the area of operations was extended to include inland bays and lakes, as well as offshore waters, and releases were made in Alabama and Mississippi in addition to Louisiana.

Field work has been so extensive that very little time has been available for analysis of the data gathered. Preliminary observa-

tions indicate, however, that east of the Mississippi River the shrimp do not confine their movements within State boundary lines. Shrimp tagged in Louisiana were recaptured in Mississippi; Mississippi releases were taken both in Alabama and Louisiana; and Alabama shrimp were returned from both Mississippi and Louisiana waters.

The shrimp tagged and released to date must be regarded as only a beginning of an extensive program. The highly variable characteristics of almost all aspects of shrimp life and behavior make an unusually large amount of data necessary in order to approximate more closely the average. To obtain a complete picture of the movements in the Gulf populations the tagging should be extended to the eastern limit of the fishery, near Carrabelle, Fla., and westward along the Texas coast. The young shrimp inhabiting the inland marsh areas should be marked to follow their growth rate and to determine the factors influencing their egress to the fishing grounds. A considerable number of large spawning shrimp should be permanently branded to determine the possibility of their living more than 1 year, and to follow their spawning movements. The accomplishment of these objectives will require a period of several years and will necessitate the tagging of many thousands of shrimp.

NORTH PACIFIC AND ALASKA FISHERY INVESTIGATIONS

DR. FREDERICK A. DAVIDSON, *in charge*

The North Pacific and Alaska fishery investigations, with headquarters in the Fisheries Biological Laboratory at Seattle, Wash., are concerned with the solution of problems that arise in the maintenance and rehabilitation of the salmon populations of the Columbia River and Puget Sound and the salmon and herring populations of Alaska. All of the major investigations that were in progress in 1938 were continued in 1939.

COLUMBIA RIVER

The investigation of the biological and physical factors influencing the populations of fish inhabiting the Columbia River and its tributaries was continued during 1939 by J. A. Craig, A. J. Suomela, M. G. Hanavan, Z. E. Parkhurst, R. L. Rucker, and J. R. Coleman.

Since it was necessary to detail practically the entire personnel of this investigation to the fish-salvaging work, it was not possible to conduct any stream surveys during 1939.

Migratory fish salvage.—The Grand Coulee irrigation project, now being carried out by the Bureau of Reclamation, U. S. Department of the Interior, makes necessary the erection of Grand Coulee Dam across the Columbia River at a point some 128 miles up-river from Wenatchee, Wash. This structure will be about 330 feet high, from river level to crest, when completed. Because of the great height of the dam, it was decided that it would not be feasible to pass adult migratory fish over the dam on their upstream journey, nor their offspring over the structure in their downstream migration.

Since this situation prevailed, and since significantly important runs of chinook and blueback salmon and steelhead trout normally proceed upstream beyond Grand Coulee Dam, it was necessary to devise and carry out plans for the protection or salvaging of these

runs of fish. The method decided upon provided for the trapping of all upstream migrant salmon and steelhead trout at Rock Island Dam near Wenatchee, Wash., and the construction of holding ponds and a large hatchery on the Icicle River, a tributary of the Wenatchee River, near Leavenworth, where the adult fish would be held until the sex products were ripe and the fish were stripped. Subhatcheries, or rearing stations, located on the Methow, Entiat, and Okanogan Rivers are also part of this plan. These stations are to be used for the hatching of the eggs taken from the adults at Leavenworth, after which the young fish will be reared and liberated in the river system where the subhatcheries are to be located. All of these streams enter the Columbia River below Grand Coulee Dam and above Rock Island Dam. Because of the fact that chinook and blueback salmon have an extremely strong and uniform habit or tendency to return to the stream in which they were reared and liberated, it is believed that the fish resulting from the hatchery operations will return to these streams below Grand Coulee Dam, thus making trapping operations unnecessary at some future date.

By the spring of 1939 the construction of Grand Coulee Dam had proceeded to such a point that fish could no longer pass beyond the dam site. Unfortunately, construction of the hatcheries was unavoidably delayed. Therefore, emergency measures had to be taken to accomplish the salvaging of the runs.

It was decided to trap the fish in the fish ladders at Rock Island Dam and to transport them to 3 of the streams entering the Columbia between that place and Grand Coulee Dam, where they were liberated and allowed to spawn naturally. In this way the transfer to the streams below Grand Coulee Dam was begun, but with natural spawning taking the place of the hatcheries.

The permanent trapping equipment at Rock Island Dam was completed last spring and was used to catch the fish in the salvage program. Also, 8 specially built tank trucks, which will be used to transport fish from Rock Island Dam to the Leavenworth hatchery, were used to haul the salmon and steelhead trout to the desired locations. These trucks each have a capacity of 1,000 gallons and are equipped with auxiliary motors, pumps, and compressors which aerate and circulate the water in the tanks. The water is cooled by circulation through ice compartments.

Because of information previously collected by the stream-survey crews, it was possible to select areas in the Wenatchee, Entiat, and Okanogan River systems which were suitable for the spawning activities of the salmon and steelhead trout. Chinook salmon and steelhead trout were placed in Nason Creek, an upper tributary of the Wenatchee River, the main Wenatchee just below Wenatchee Lake, and in the "stillwater section" of the Entiat River. The young of the blueback salmon require a lake for their fresh-water habitat; so that species was planted in Wenatchee and Osoyoos Lakes. Fish weirs, or racks, were constructed at the lower end of each stream section or lake in which the spawners were placed, so that the fish would not stray downstream and perhaps back into the main Columbia where they might be unable to find or reach suitable spawning areas.

The actual hauling of fish began on May 1, and the last load was transported on December 9. All of the salmon in the 1939 run were

trapped at Rock Island before hauling ceased, and few, if any, steelhead trout ascend the upper Columbia in the winter. During the May-December period 41,722 fish were hauled. The totals by species are as follows: Chinook salmon, 11,206; blueback salmon, 19,591; silver salmon, 13; steelhead trout, 5,427; squawfish, 1,771; suckers, 3,389; chubs, 133; whitefish, 163; Dolly Varden trout, 1; carp, 2; tench, 1; and lamprey, 25. Every effort was made to sort out the scrap fish, such as suckers, squawfish, etc., so that they would not be hauled along with the salmon. This practice was in general successful, but all of the undesirable species could not be eliminated from the loads.

Careful and complete observations and records were made of the entire salvage operations. The records included the number and species of all fish trapped and hauled each day in each truck, and to each location. The number and species of all fish that died during the hauling or trapping operations were also recorded. Temperature readings of the water in the Columbia River, the tank trucks, and the streams or lakes where plants were made, were obtained. Also, determinations were made of the free carbon dioxide, dissolved oxygen, pH and alkalinity of the Columbia River, the water in the trucks and in the streams where the fish were planted. After the fish were liberated, continuous limnological observations were carried on in the areas where the fish were confined. All dead fish were examined to determine whether or not they had spawned, and aquatic-food samples were taken from the streams. The success of the spawning was recorded and some of the nests were examined to discover the degree of development and the mortality of the eggs. Samples were taken of young steelhead trout from the early spring spawning so that growth could be studied.

The loss of fish during trapping and hauling was extremely small and the mortality in the streams and lakes after the fish were liberated and before they spawned was not excessive, except in the Entiat River where a bacterial fungus infection caused a significant percentage of the spawners to die before they had matured and deposited their eggs.

It is felt that the analysis of these data will contribute significantly to our knowledge of the habits of chinook and blueback salmon and steelhead trout, as well as present a valuable account of a practical fish-salvage operation.

Tagging.—Five tagging experiments were conducted near the east end of Sand Island, at the mouth of the Columbia River, on blueback salmon from June 11 to July 9, inclusive. The purpose of these experiments was to obtain data on: (1) The rate of migration of the salmon upstream; (2) their distribution in the river system; and (3) some estimates of fishing mortality.

During the operations 238 blueback salmon were tagged and liberated, of which 61, or 25.6 percent, were recovered from the commercial fishery.

Additional catch records of the commercial fishery were tabulated and summarized to be used in studying the movements and abundance of the salmon populations.

Construction of fish protective works.—The program of fish-screen construction in eastern Washington, Idaho, and Oregon was con-

tinued under the supervision of J. A. Craig and O. W. Lindgren, and was accomplished with the aid of W. P. A. and P. W. A. funds. During 1939 the construction of the screen in the Wapato Canal, near Yakima, Wash., the work on the Sunnyside screen, and the construction of the screen in the Echo Feed Canal in Oregon, were completed. Both of the canals are property of the U. S. Bureau of Reclamation. Contract work on the screen at the Black Canyon Dam canal of the Bureau of Reclamation, on the Payette River in Idaho, was begun in December and all contract and other work on the screen in the Prosser Power Canal of the same agency, near Prosser, Wash., was almost completed at the end of the year.

COHO SALMON

The coho salmon of Puget Sound are not only of importance to the commercial fishery of the region, but likewise to the sport fishery which forms one of the Pacific Northwest's most valuable recreational assets. The study of the life history of these salmon, and the causal factors responsible for fluctuations in their abundance, was conducted by George B. Kelez until May 1939. Owing to Mr. Kelez' assignment to the study of the Bristol Bay salmon, Dr. J. L. Wilding, formerly with the Columbia River investigation, took over the study of the coho salmon.

Marking experiments.—Final returns from the 1937 marking experiments at the Bureau's Quilcene (Wash.) Hatchery were collected at the hatchery rack in the fall of 1939. During this period the rack was covered twice by flood waters and some of the fish escaped to the upper river. Of 148 adult fish taken at the rack, 67 were marked. Thirty-eight of the recoveries were from the lot of 24,600 fingerlings marked and released in August and September 1937, 25 were from the lot of 20,039 fingerlings marked and released in December 1937, and 4 were from the lot of 17,094 fish marked and released in May 1938. Two additional recoveries from the December 1937 release were made in salt water near the hatchery.

The results of these experiments show that the fall release of fingerlings produced slightly better returns than the midwinter release, with less expense for handling and feeding, and the spring release of fingerlings in their second year produced much smaller returns than did the preceding releases.

Returns from the belly-tagged fingerlings released at the State of Washington's Samish River Hatchery in 1937² also were recovered in the fall of 1939. One adult fish was returned from the October release, 15 were recovered from the December release, and 3 recoveries were made of fish which had not retained the tags. Although these returns were sufficiently large to warrant further experiments, mortality appeared to be considerably higher than that of fish marked by fin incision only. The survival of winter-tagged fingerlings was much greater than that of fall-tagged fish.

Young fish, and fish-food studies.—A study of the seasonal fluctuations in numbers of young fish and abundance of the fish-food organisms in the various streams of the region frequented by the coho salmon was begun. This study was also planned to include a corre-

² See "Progress in Biological Inquiries, 1937," p. 30.

lation of the fish food present with the food organisms consumed by the coho young from the time of hatching until their seaward migration. This procedure, together with a study of the influence of varying environmental conditions on the growth and time of seaward migration of the young, was aimed to give insight into the fresh-water mortality of the species.

In order to locate suitable key streams for these studies a general survey was made of the important streams in the region. Five tributaries were selected, each of which differed from the other in its source, distance from salt water, size, shaded areas, type of bottom, mean temperature, and, to some extent, in chemical composition. The selection of streams with varying environmental conditions was made in order to include the important fresh-water habitats frequented by coho salmon.

A new type of sampler for streams, designed by Dr. Davidson and Mr. Kelez, is being used to determine qualitatively and quantitatively the bottom fauna and its variations. The new sampler is more efficient than net types, since it can be used in a variety of locations such as in sand, mud, vegetation, and gravel, and it takes an exact quantitative sample. An example of its efficiency is shown by the numbers of Chironomidae larvae that are consistently taken in the sampler, whereas these forms are usually, if not entirely, missed by other samplers due to the small size of the larvae and their depth in the gravel. Collections of chemical and physical data on the streams, bottom samples, and coho fry or fingerlings are taken each month.

Hatchery experiments.—In cooperation with the Division of Fish Culture, a series of experiments are being conducted to test the reactions of coho fry and fingerlings to various concentrations of sea water. The relative tolerance to salt water, and rapidity of adaptation to higher concentrations exhibited by fish of varying age, would have a definite bearing on the time of release of hatchery-reared fish. The experiments were begun at the Quilcene Hatchery in November.

SURVEY OF ALASKAN LAKES

Dr. Wilding was detailed to southeastern Alaska from July to October to study certain lakes and streams in cooperation with the U. S. Forest Service. The purpose of the survey was to determine the physical, chemical, and biological characteristics of the waters in order to formulate a trout-stocking and conservation program. Ten lakes in Southeastern Alaska, and Wonder Lake in McKinley Park, were surveyed. The analysis of the lakes included: Temperature series, dissolved oxygen and free carbon dioxide, pH, carbonates, bottom fauna, fish, and plankton samples. The amount and suitability of spawning area was determined and fish- and egg-planting sites were located. In certain general characteristics the lakes were quite similar, especially in regard to their oligotrophic nature, high oxygen content, low bacterial decomposition and carbon-dioxide content, slightly acid reaction, absence of vegetation, and scarcity of bottom organisms. The plankton population was extremely variable from lake to lake, and in general there were numerous organisms of a few species. A detailed report of the investigation has been prepared and a stocking policy recommended.

BRISTOL BAY SALMON FISHERIES

The Bristol Bay area, which produces more than 60 percent of the pack of red salmon in Alaska, is one of the greatest salmon-producing districts in the world. During 1939 this area produced 54½ million pounds of canned salmon. This pack was 5 million pounds below the average for the preceding 10 years, the curtailment being due, in part, to a shortening of the fishing season by the Bureau in order to insure the escapement of an adequate number of spawning fish to the tributaries in the various watersheds.

The determination of the causal factors affecting the fluctuation in abundance of the salmon runs in this region is the fundamental purpose of the investigation being conducted by Mr. Kelez and Joseph T. Barnaby, assisted by Walter Sands, Albert Collier, and Robert Hacker. The problems entailed in the investigation are manifold, including a complete study of the life history of all the races of salmon populating the lakes and rivers in a watershed of over 35,000 square miles. In addition to the studies on the fresh-water phase of the life history of the red salmon, studies must be made of the factors that influence the growth, mortality, and migrations of these fish during their sojourn in the ocean.

Fresh-water studies.—Investigations of the fresh-water phase of the life history of the red salmon of the Bristol Bay region were carried on during the season of 1939 at field camps established on 5 of the main rivers during the summer, and on the watersheds of these streams during the fall. A camp at the foot of the Naknek River rapids was established on May 19; 1 at the head of the Ugashik River lagoon on May 24; 1 on the Kvichak River, at the foot of Kas-konak flats, on May 25; 1 below the Egegik River rapids on May 27; and 1 on the Wood River at the foot of Marsh Mountain on May 31.

Regular samples of seaward migrant fingerlings were taken at each camp, collections of other fishes were made, and fingerlings were marked for future identification in the rivers where they were available in sufficient numbers. Daily records of weather conditions, stream levels, and air and water temperatures were kept throughout the season until the parties moved to the upper watersheds for spawning observations. The stream observations will be correlated with annual meteorological data collected by the U. S. Weather Bureau at 3 stations in the Bristol Bay region.

The spring break-up was very late in 1939, particularly in the Wood River watershed, where ice, carried down from the Wood River lakes, seriously interfered with seining activities as late as June 13. Fingerlings were available in sufficient quantities to warrant marking only in the Naknek and Wood Rivers, although small numbers of migrants were taken in the other streams.

Migrants were taken in the Naknek River from May 31 to August 15, but less than 100 per day were caught prior to June 14. Marking, by excision of the dorsal and right ventral fins, was begun on June 16 and terminated on August 14. All marked fish were retained in holding pens for 24 hours after marking in order that the losses due to handling might be determined. The total release of marked fish in this area was 26,419. The Naknek fingerlings were large, averaging about 113 mm. in length, and were in good condition; losses due

to handling were small. The recovery of these marked fish as adults will afford data on life history, points of capture in the commercial fishery, and mortality in the ocean.

Fingerlings were taken in the Wood River from June 4 to August 22, and marking was carried on between July 3 and August 14. Abnormal water levels in the river during the month of June followed the late break-up of ice on the Wood River lakes. A peak rise of more than 45 inches during this period reduced the number of locations suitable for fishing activities appreciably. The water level dropped gradually thereafter throughout the season, a condition exactly opposite to the normal occurrence in the Bristol Bay streams. The total release in this area was 11,338 fingerlings, marked by the excision of the adipose and left ventral fins. The Wood River fingerlings were much smaller than those of the Naknek area, their general condition was poor, and they were further weakened by a high degree of infestation by cestodes. Losses due to handling aggregated nearly 20 percent of the fish taken; an exceptionally high mortality for wild fish.

During the commercial-fishing season 1 man was stationed at each of the main rivers to obtain regular scale samples, body measurements, weights, and sex proportions from the catches of the commercial drift-net fishery. Additional samples were taken from the fish caught by set nets within the rivers. These data will provide information concerning the age of the mature fish, material for racial comparisons, and a basis for the determination of gear selectivity.

The field parties were moved to the tributaries of the respective rivers during August for the purpose of making surveys of spawning grounds. In the course of the surveys, actual numbers of spawners were counted in various streams and their tributaries. The rate of water flow, temperatures, stream-bed characteristics, and the extent of the spawning areas were determined. Body measurements, scale samples, and data on various morphological characters were obtained from spawners in these areas for racial comparisons. Of the spawning tributaries thus investigated, 3 were rivers, 7 were major streams, and 19 were creeks. The field parties returned to Seattle via the Iliamna Lake portage on September 6.

In addition to the above-mentioned activities, several lakes were surveyed by Mr. Kelez as possible sites for survival studies on eggs and young fish. All major spawning areas were covered at least twice during the season by aerial survey, and spawning-ground estimates thus made were correlated with the work of the field parties. A new method of making a population census by means of aerial photographs was begun. While still in the experimental stage, this method holds much promise in that it makes possible a determination of the distribution of spawners in inaccessible areas, or in those areas where the cost of ground surveys is prohibitive.

For Bristol Bay in general, the escapement of 1939 was considerably less than that of 1938, the Kvichak area showing the greatest proportional decrease. The Naknek and Egegik areas indicated uneven distributions and decreased total numbers of spawners, while the Wood River and Nushagak escapements were more nearly equal to those of 1938. The Ugashik area had a somewhat better escapement than that of 1938, although the spawning ground in this district was still not adequately seeded.

Marine studies.—Investigation of the marine phase of the life history of the Bristol Bay populations is not only important in order to determine the factors influencing the salmon growth and survival, but is also of importance in ascertaining the magnitude of the commercial catch, since part of the run of fish is captured 400 to 500 miles from the home streams of the salmon.

Tagging experiments were carried on in the Shumagin Island area and in the Ikatan-Morzhovoi Bay area to determine the migration routes and destinations of the salmon frequenting those areas. In these experiments, mature salmon on their spawning migration were tagged by means of an aluminum strap-tag which was attached to the dorsal part of the caudal fin. The experiments were similar in nature to those carried on in 1923 by Charles H. Gilbert and Willis H. Rich.³

A greater return was obtained from the 1939 Shumagin Island tagging than was obtained in 1923, the recovery being 34.5 percent as against 28.7 percent in 1923. A much higher percentage of the fish was caught locally, 22.6 percent in 1939, compared with 2.6 percent in 1923. A greater percentage of returns was taken to the eastward, 4.3 percent in 1939, and 0.5 percent in 1923. Most of the returns came from Chignik, which experienced a good run during the past season. Lower percentages were recovered from Ikatan and Bristol Bays in 1939, 3.0, and 1.2 percent, compared to 11.1, and 9.2 percent, respectively, in 1923.

The 1939 study of the migration of fish around the Shumagin Islands supports the conclusion that as many fish traveled up Popoff Straits as migrated down the Straits. The results, therefore, do not confirm the conclusion made by Gilbert and Rich on the basis of the 1923 study that "the majority of the salmon that escape the traps in the region of Kelly Rock skirt the south shore of Unga Island * * *."

The return from the Ikatan tagging experiments was 37.0 percent in 1939 as against 44.6 percent in 1923. Fewer fish were recaptured locally in 1939; 19.7 instead of 34.0 percent. A slightly higher percentage migrated eastward; 1.0 compared to 0.3 percent in 1923. A smaller number was taken in Bristol Bay; 4.0 percent in 1939 and 6.2 percent in 1923. The lower percentage of recovery in the Bristol Bay area was due in part to the fishery on the south side of Unimak Island, which recaptured 10.8 percent of the fish tagged, whereas in 1923, this fishery was not in existence and consequently once the fish left Ikatan Bay they were not intercepted until they reached Bristol Bay. Of special interest is the evidence indicating that at least a fair proportion, if not a majority, of the Bristol Bay fish which pass the Shumagin Islands and Ikatan Bay proceed to Bristol Bay along the south shore of Unimak Island, and thence probably through Unimak Pass. Gilbert and Rich (loc. cit.) concluded that most, if not all, of the Bristol Bay fish found in the Shumagin Island and Ikatan Bay area proceeded through False Pass on the way to their home streams. Although those authors pointed out that fish may enter Bering Sea through other passes, they also stated that "no such migration through western channels has ever been reported."

³ Second experiment in tagging salmon in the Alaskan Peninsula Fisheries Reservation, summer of 1923, by Charles H. Gilbert and Willis H. Rich, Bulletin, U. S. Bureau of Fisheries, vol. 42, 1926, pp. 27-75.

In the 1939 experiments a smaller return was made locally from the tagging at East Anchor Cove than was made from the tagging close to False Pass, indicating that in general the fish were moving away from the Pass. The relatively high percentage of marked fish recovered south of Unimak Island, and the abundance of migrating red salmon along this entire shore, shows that a fairly large number of fish travel by this route after leaving Ikatan Bay. These fish would enter Bristol Bay via Unimak Pass or other passes to the westward.

Local fishermen who have tried to catch fish in False Pass report that there are no red salmon to be found in the northern half of the Pass, and that while red salmon enter False Pass they do not go through but return to Ikatan Bay. While it is possible that some red salmon do go through False Pass, it is certain that a fairly large number proceed from Ikatan Bay to Bristol Bay via Unimak Pass and other passes to the westward.

A study of the migration routes of the Bristol Bay red salmon populations was also made in the off-shore waters, both north and south of the Alaska Peninsula, by operating various types of fishing gear at varying distances from shore. The data obtained from this research are of considerable value in determining the areas traversed by the salmon on their return to their home streams, and also the types of organisms taken by them for food.

The U. S. Coast Guard again cooperated with the Bureau of Fisheries by furnishing the cutter *Redwing* for the purpose of conducting the oceanographic survey of Bristol Bay and contiguous waters. New anchor gear and a sonic depthfinder were installed on the *Redwing* early in the spring to facilitate the carrying on of the oceanographic studies, which require numerous stops for samples and for frequent and accurate soundings.

Samples were obtained at all stations in Bristol Bay proper prior to the time of the fish run, during the run, and again after the run has passed by. In addition, some samples were taken between Unalaska Island and the Pribilof Islands. Temperature data and plankton samples were collected, and chemical analyses were made of the water taken at various depths from each station, to determine the oxygen, chloride, silicate, phosphate, and nitrite content of the water. The purpose of the oceanographic surveys is to determine the environmental conditions in the areas in which the fish spend a part or all of their sojourn in the ocean.

KARLUK RIVER RED SALMON

Further studies to determine the extent and causes of the fluctuations in the size of the red-salmon runs to the Karluk River, Alaska, were conducted in 1939 by Allan C. DeLacy and William M. Morton. The period of field work extended from May 1 to October 5, and the tabulation and analysis of data occupied the balance of the year.

The runs of red salmon to the Karluk River have shown great fluctuations in abundance during the 19-year period in which they have been under observation by the Bureau of Fisheries. From 1887 to 1908 the commercial catch of red salmon in the Karluk area averaged 2,500,000 fish per year. Following this period, the commercial catch has exceeded 2,000,000 fish in only 1916, 1917, and

1926. With the establishment of a counting weir in the river in 1921, and the passing of the White Law in 1924 (43 Stat. 464), a 50 percent escapement of fish to the river has been required. This limited escapement has curtailed the commercial catch in the area, and since 1924 the total run of red salmon to Karluk has exceeded 2,000,000 fish in only 8 years; in only 2 of these 8 years did the total run exceed 3,000,000 fish.

In view of the decline in the productivity of the Karluk River every effort is being made to determine its cause, with special emphasis on the factors responsible for the mortality of red salmon during their fresh-water and marine existence. Because of the greatly varying environmental conditions in the river system, it has been found that the number of mature salmon necessary to adequately seed the spawning grounds may fluctuate considerably from year to year. The mortality of the salmon during their fresh-water existence has been traced to the influence of environmental conditions on the spawning grounds and to seasonal fluctuations and periodic trends in the fertility of the lake, which are responsible for corresponding variations in the abundance of the food available to the young fish and the influence of fresh-water predators.

An intensive study has been made of the mortality of the red salmon during their marine existence by means of consecutive yearly marking experiments from 1926 to 1936, inclusive. The results of this study indicate that there is a fairly constant mortality of the salmon in the ocean which averaged 79 percent during the 8-year period of study.

A complete report of the activities and results of this investigation of the Karluk red salmon, from 1926 to 1936, has been prepared by J. T. Barnaby and submitted for publication. Mr. Barnaby conducted this investigation from 1929 to 1938 and then was transferred to the Bristol Bay investigation.

Migration studies.—Red-salmon fingerlings migrating to the ocean were first seen in abundance at the Karluk weir on June 1. The migration continued for about 2 weeks and appeared to be normal in size. Samples of the fingerlings were taken to determine the age composition of the migrant run, and the average length of the individuals in each age group. The 1939 migrants were of average size and were considerably larger than the 1937 and 1938 migrants.

Between May 21 and September 23, 666,004 adult red salmon were counted as they passed through the weir, and it was estimated that after the removal of the weir on September 23, 40,000 additional red salmon ascended the river. Only twice before, over a period of 19 years, has the escapement been less than in 1939. However, conditions on the spawning grounds appeared to be favorable, and a fair to good return is anticipated, despite the relatively small size of the escapement.

The number of pink salmon passing through the Karluk weir was 31,944. This is the largest odd-year escapement of pink salmon since 1933, and it is evident that the 2-week cessation of commercial fishing in the Karluk area, between July 24 and August 5, was beneficial.

Racial study.—It has long been recognized that the run of adult red salmon to the Karluk River is characteristically divided into 2 parts. The first peak of abundance occurs in June, and the second

in August or September. If the fish that constitute these 2 runs are hereditarily distinct, then it is apparent that conservation measures must be designed and carried out in such a manner that each group will receive adequate protection. To ascertain whether or not the two runs are racially distinct, morphometric data were collected from 448 red salmon during the 1939 season between June 7 and September 16. Twenty-one measurements were made on each fish examined, and in addition the gillrakers were counted. A statistical treatment of the data will reveal any dissimilarities between the two runs of Karluk fish. A large sample of pink salmon also was measured for racial characteristics to be included in the racial studies of the pink salmon in Alaska.

Egg counts.—Counts were made of eggs collected in 1938 from 60 red salmon that ranged from 51 to 65 centimeters in length. The left ovary was found to contain a higher average number of eggs than the right ovary, although in similar counts made in 1926 the reverse of this condition usually was found. The 1926 sample of fish averaged 3,728 eggs per individual. The 1938 average for a comparable group of fish was 3,218. In general, the larger the fish the greater was the discrepancy between the results of the 2 years' tabulations. One hundred and twenty additional egg samples were collected during the 1939 season and will be used to supplement the 1938 data, and to determine whether or not the number of eggs per female varies from year to year.

DOLLY VARDEN TROUT

Life-history studies were continued at Karluk in 1939 on the salmon predator *Salvelinus malma*, commonly known as the Dolly Varden trout, or char. From tagging experiments started in 1937 and 1938 a total of 875 tags were recovered. Two tagging and three marking experiments were initiated in 1939. During the upstream migration of Dolly Varden trout in July, 2,695 fish were tagged at the Karluk weir, and at a weir built in Thumb River—the largest tributary of Karluk Lake—1,463 additional chars were tagged in late summer. One marking experiment was made at the Karluk weir in which the adipose and both ventral fins were amputated from 2,038 Dolly Varden trout between 21 and 25 cm. in length. At the Thumb River weir the adipose and left ventral fin were clipped from 543 fish between 16 and 20 cm. long, and the adipose and right ventral from 178 chars between 11 and 15 cm. in length. Returns from these marking experiments will supply data concerning the growth rate and migration of a group of small fish which it is difficult to tag successfully.

The conclusion that there are at least 2 populations of char in the Karluk system was reached after the tag recoveries made in 1937 and 1938 had been analyzed. The presence of a nonmigratory lake population and a population which annually migrates to and from the ocean was shown. In 1939 additional tag returns and a study of the morphological characters of the Karluk chars confirmed the foregoing conclusion. The total number of gillrakers proved to be a useful diagnostic character. The stationary, or lake-type char was found to have an average of 23.4 (21 to 26) gillrakers, while in the

migratory, or ocean-type char the average number of gillrakers was 18.4 (17 to 21). Some of the other characters which differ in the 2 types are the coloration, average number of vertebrae, length of head, diameter of eye, and depth of caudal peduncle.

Returns in 1939 from 2 tagging experiments in progress at Karluk Lake again pointed to the lack of homogeneity in the lake's char population. Fish tagged in 1937 were still most commonly found in 1939 at the mouths of the same streams at which they had been tagged 2 years earlier. Further study will be required to determine the presence or absence of races of chars within the lake itself.

PINK SALMON

The study of the causal factors responsible for the fluctuations in the abundance and seasonal time of the spawning migration of the pink salmon in Alaska was continued during 1939 by Dr. Davidson and S. J. Hutchinson.

The pink salmon are by far the most abundant species of Pacific salmon in Alaska. During the past 10 years an annual average of 3,150,748 cases of pink salmon have been packed, whereas the red salmon, which are second in abundance, have yielded an average of only 1,908,072 cases yearly. The pink salmon have a lower market value than the red salmon. The 1930-39 annual average catch of pink salmon was valued at \$13,346,874, while the corresponding average value of red salmon was \$15,798,340.

Because of the complete 2-year life cycle of the pink salmon it is possible to build up or break down a population of the species within a few years. The record packs of pink salmon from 1934 to 1938 have been due in part to the successful reproduction of the species, and in part to the increase in the intensity of the fishery. The size of the spawning populations in 1937 and 1938, in some areas, was far from comparable to the total catches of the fishery, and a marked reduction in the ensuing populations was predicted. The unusually small packs of pink salmon in 1939 in Central Alaska, with the exception of the Kodiak and Cook Inlet areas, and in Southeastern Alaska, were to be expected. In Southeastern Alaska the intensity of the fishery has been mounting in spite of warnings from the Bureau of poor escapements and unfavorable spawning conditions. A number of needed restrictive regulations were recommended for the pink-salmon fishery in the Central and Southeastern sections for 1940. In view of the almost complete lack of escapement in some areas in the Southeastern section in 1939, an extensive curtailment of the fishery will be imperative in 1941 if the populations in these areas are to be kept above the critical point of depletion.

One of the most important factors in the reproduction of the pink salmon is the mortality that occurs during their fresh-water existence. The stream at Little Port Walter, on Baranof Island in Southeastern Alaska, was selected as a site where fluctuations in the fresh-water survival of the pink salmon could be determined and the causes thereof studied. In March and April, 1939, a combination stop-log dam and counting weir was constructed in the stream at Little Port Walter which will permit the counting of both the upstream and downstream pink salmon migrants. The counts will make possible the determina-

tion of the number of fry resulting from the spawning of a known number of eggs each season. The adults returning from the liberation of a known number of fry each season will be determined from the subsequent spawning populations, and in this way the percentage of mortality during both the fresh-water and salt-water existence may be calculated.

In order to carry on the necessary weekly observations of the influence of environmental conditions on the brood in the stream, and conduct laboratory experiments on the salmon leading to a better understanding of their reactions to certain environmental factors, a laboratory-residence building was constructed at Little Port Walter during the past summer. A permanent biological station foreman will be appointed for the purpose of maintaining the equipment at the station and making the necessary biological observations regarding the survival of the salmon in the stream. It is expected that the results from the continuous operation of this field station will give insight into the survival of the pink-salmon brood in this region of Alaska each year, and permit more accurate predictions as to the size of the annual runs of pink salmon.

Spawning escapement.—The first count of adult salmon through the weir at Little Port Walter in 1939 was made on August 17, and by August 22 the run was well under way. A total of 16,830 pink, 122 coho, 117 chum, and 7 red salmon was counted through the weir. Of the 16,830 pink salmon, 51.56 percent were males, and 48.44 percent were females. The pink-salmon escapements through the weir at Little Port Walter prior to 1939 were: 1934, 6,952; 1935, 6,073; 1936, 5,164; 1937, 7,085; and 1938, 6,467. The adults in 1939 came from the spawning population of 1937, and, since the commercial fishery at Little Port Walter has been negligible, this is the first year when the returns were greater than $1\frac{1}{4}$ to 1. Unfortunately, it cannot be determined whether this survival occurred in the salt-water or fresh-water period, but such fluctuations in the future, it is hoped, may be traced to the influence of certain environmental factors.

Tagging program.—With the opening of the commercial fishing season in Eastern District on July 5, a pink-salmon tagging program was instigated. Pink salmon were tagged and released each week end throughout the fishing season. All the tagging was conducted from the 2 traps in Tebenkof Bay, which are the first traps encountered by the migrating salmon as they enter Chatham Straits from the south and travel the inside waters to their spawning grounds in Frederick Sound and contiguous waters. A total of 2,100 pink salmon were tagged during the season. The general trend of the migration, as indicated by tag recoveries, is northeast into the inside waters of Frederick Sound, Stephens Passage, and the Stikine River region. There were 684 tags recovered, yielding a 32.57 percent return from the experiment. Of this number of recaptures, the majority traveled a distance of 40 miles or more and were taken within 5 days after the tagging date. The greatest distance that a tagged salmon traveled before being recaptured was 162 miles. One specimen, taken the day after tagging, had traveled over 100 miles. Thus it becomes evident that the pink salmon entering Lower Chatham

Straits are not destined to any one particular locality, but are quite diversified in their routes of migration. Tagged pink salmon were recaptured in 26 different salmon traps in Western District, in 36 salmon traps in Eastern District, in 16 traps in Sumner Strait District, and in 1 trap in Clarence Strait District. Seine boats reported captures in 19 localities, and gill nets in one location. Of the total of 684 recaptures, 551 were made by traps, 128 by seine boats, 2 by gill nets, 2 from streams, and 1 unknown. The traps caught 80 percent of the tagged salmon that were recaptured, the seine boats 19 percent, and 1 percent was taken by miscellaneous gear.

Racial study.—A racial analysis of the pink salmon in Southeastern Alaska is being made. The first step in the analysis is to determine from body measurements suitable indices for comparing the populations, i. e., ratios of measurements that are characteristic of each population. At present, 15 ratios have been devised and are being tested to determine their reliability as racial indices. After these racial indices are determined, the experiment will reduce to the comparison of populations from various localities using these indices and thus determine the races of pink salmon existing in Southeastern Alaska.

ALASKA SALMON STATISTICS

The collection, tabulation, and analysis of the daily catch records from the various types of fishing gear operated by the salmon fishery in Alaska was continued in 1939 by Elizabeth Vaughan. The purpose of this investigation is to provide a permanent source of information from the daily catch records of the various forms of gear from each of the geographical divisions of the territory. These records provide an invaluable part of any investigation of the fisheries, and will make possible a complete survey of the industry year by year. The single comprehensive compilation will avoid duplication of effort which would inevitably result from the individual collection of statistical data by several investigators, and will insure the collection of much valuable data which would almost certainly be lost with the passage of time and changes in the companies operating, were the collection delayed until further investigation was undertaken. To eliminate duplications and losses, the statistical investigation was originated with the following specific aims: (1) To collect all available records of the daily catch of salmon in Alaska from each form of gear; (2) to add to those early records the current data as it becomes available each year; (3) to index carefully and segregate the data by area, species, and type of gear; and (4), to tabulate the data into usable form, and to analyze these tabulations as may be required in the study of specific problems.

During the past years, all available records have been collected. The analysis of the trap-catch records for the Southeastern Alaska and Prince William Sound fishing districts have been made for the pink and chum salmon.

During 1939 the data on the 1938 fishing season were collected, and the analysis of the trap-catch records of the pink and chum salmon for the Southeastern Alaska and Prince William Sound districts was added to the analyses for previous years. The analysis consists of determining the average daily catch per trap for each fishing

season, by district. Indices of abundance and seasonal time of appearance of the salmon runs are determined from these daily averages. This information is used as a basis for recommending changes in the fishing regulations in Alaska in order to provide for the conservation of the salmon resources.

During 1939 the records from the Alaska Peninsula, Chignik, Kodiak Island, and Cook Inlet trap fisheries were sorted and indexed. The tabulation of these data will be begun in the near future.

HERRING

Three major areas of the Territory of Alaska at present support extensive commercial herring-fishery operations; these being Kodiak, Prince William Sound, and Southeastern Alaska. The investigation of the herring fisheries, which was continued throughout the year by E. H. Dahlgren and L. Kolloen, was primarily concerned with the following problems: The delimiting of the areas frequented by the various races or populations comprising the stocks of herring; an evaluation of the abundance of the populations supporting each of these fisheries; the measuring of changes in fishing intensity; and the determination of fluctuations in annual increments to the population, and the factors governing these fluctuations.

Kodiak area.—In the Kodiak area the largest catch ever recorded was made in 1939, with a total take of 309,000 barrels. However, the total catch of itself has no significance as a measure of abundance unless correlated with the fishing effort required to make it. Since the inception of reduction operations in this area in 1935, the herring fishery has undergone a tremendous expansion. Reduction capacity has increased from 15 tons of raw fish per hour in 1935, to 45 tons per hour in 1939; the number of vessels engaged has increased from 11 to 21; and, with a tendency toward the use of larger vessels, the fishing capacity of the fleet has increased threefold. In order to establish a trend of abundance, the number of vessels, weighted by their net tonnage in order to account for the greater efficiency of larger vessels, multiplied by the number of days each vessel operated in the area, was divided into the total catch for the year to give the average catch per ton-day of fishing effort. These data were compiled for each year since the inception of the reduction industry in 1935. The catch in barrels per ton-day fished rose from 6.4 in 1936 to a high of 7.5 in 1937 and has declined to a low of 4.5 in 1939.

The great abundance of herring in the Kodiak region during the past 5 years has been in part the result of the accumulations of the stocks during the less intensive operations previous to 1935. A further factor that contributed to the high abundance level has been the presence in the catch of the offspring of the dominant 1931 year-class. The phenomenon of dominance of certain year-classes, with the attendant great natural fluctuations in abundance, results from an occasional remarkably successful spawning, in consequence of which large numbers of larvae survive to enter the adult populations 3 years later. In contrast, spawnings in immediately previous or subsequent years are not so successful—some may even be virtual failures and contribute no appreciable increments to the stocks. Daily samples of the catch were taken throughout the season and ages were read

from the annuli on the scales, in order to establish the relative abundance of the various age groups represented in the catch in relation to comparable data obtained in previous years.

In 1937, the first year for which adequate data are available for the Kodiak region, the 1931 year-class constituted 70 percent of the total number of fish taken. In 1938, with the entrance of the 1935 year-class into the catch, the year-class of 1931 declined to 49 percent of the total yield. Age readings of approximately 2,500 individuals during the 1939 season revealed that the catch was still composed of 20 percent of the 1931 year-class even after 5 years of fishing had decimated its numbers, and also confirmed the previous findings that the spawnings of 1932, 1933, and 1934 failed to contribute any appreciable increment to the stocks. Since the spawnings of these years added so little to the populations, and since the 1931 year-class will have been nearly exhausted by 1940, the catch during that season will become dependent almost entirely on fish spawned in 1935 and 1936. This condition does not bode well for the continuance of a high abundance level. In view of the increased fishing intensity, the declining return per unit of gear, and the decreased spread of the age composition of the stock, the need for close supervision of the herring fishery cannot be disregarded.

Prince William Sound area.—The catch in the Prince William Sound area during the 1939 season was 423,000 barrels. This total compares favorably with the average catch of 317,000 barrels during the preceding 5 years, and taken alone would indicate a healthy condition for this fishery. Considered, however, in relation to the amount of fishing effort required, and the declining return per unit of gear, together with the change in age composition, it is apparent that this area, too, will require careful supervision to avoid over-exploitation.

Reduction capacity in this area has increased from 7 tons of raw fish per hour in 1934, to 66 tons per hour in 1939 and this increase in plant capacity has been followed by an increase in fishing effort. The number of vessels employed in 1934 was 7, compared to 30 in 1939. Because of the larger vessels employed, the increase in actual capacity was in the ratio of 6 to 1. In the face of this increase in the fishing effort the catch per unit of gear, based on the catch per ton-day of fishing effort, as in the Kodiak area, has shown a progressive decline from 8.1 barrels in 1934 to 3.1 barrels in 1939.

Reduction operations in the Prince William Sound area were not intensive until after 1934, providing an opportunity for the herring stocks to build to a high abundance level. This abundance also was bolstered by the presence of a dominant 1931 year-class, as occurred in the Kodiak area. The 1937 and 1938 samples of the catch in this area were taken in the fall months only—August 25 through September. In 1939, for the first time, age-composition data are available throughout the season, and age determinations from scales of approximately 4,600 fish were made. However, since there is a change in the age composition of the catch during the season in this area, with the older fish appearing in greater relative abundance during the fall months, comparisons of the age composition of the catch with that of previous seasons has been made for the fall portion of the season only. This analysis shows that the

1931 year-class represented 54 percent of the catch in 1937, 48 percent in 1938, and 32 percent for the corresponding period in 1939. Here, again, the spawnings of 1932, 1933, and 1934 were almost total failures, their combined contribution to the catch during the fall of 1939 being less than 5 percent. With the disappearance of this dominant 1931 year-class, and because the succeeding 3 brood-years failed to contribute any measurable portion to the catch, a further decline in the population level may be anticipated in this area for the 1940 season.

Southeastern Alaska.—The season's catch for Southeastern Alaska in 1939 was 160,000 barrels, compared to a 10-year average of 434,000 barrels in the area, and was the lowest catch recorded since the inception of the intensive reduction fishery 15 years ago. The success or failure of this fishery has been dependent almost wholly on the abundance and availability of the stock of herring frequenting the Cape Ommaney area. The continuing decline in the abundance of this population, as reflected in a declining catch per unit of gear, led to a closure of the Cape Ommaney area during the 1939 season, although nearly 72,000 barrels of the total catch were taken from this same population outside of the closed area.

Samples of the size and age composition of the catch in this area were again collected. In the Cape Ommaney region, as in Kodiak and Prince William Sound, the 1931 year-class dominated the catch for several years, but by 1938, due to the more intensive fishing in this area, had practically disappeared. Here, too, the spawnings of 1932, 1933, and 1934 were virtual failures. The decline in this fishery to a dangerously low level must be attributed, in no small measure, to this failure of the young to survive.

A survey of the spawning grounds at Sitka, which is the source of the Cape Ommaney stock of herring, was made during the spring of 1939. For the second consecutive year the run in this important area was exceedingly light, giving further proof that the decline in abundance as measured by the catch per unit of gear is valid. Incidental to this survey, an effort was made to determine the effect of temperature and dessication on the survival of eggs spawned in the intertidal zone. The clusters of eggs could not be separated for microscopic examination without hardening them in a fixative. When the eggs were hardened they became opaque which precluded a determination of viability. Thus the attempt resulted only in the development of a technique for hardening, separating, and clearing eggs which will make possible future accurate estimates of mortality due to temperature and dessication.

PACIFIC PILCHARD INVESTIGATIONS

O. E. SETTE, *in charge*

The problem of the pilchard investigation is to determine the amount that can be safely harvested annually without jeopardizing future yields.⁴ This determination is complicated by the existence of natural fluctuations in abundance, which are caused by differences from year to year in the numbers of fish surviving the early stages of life. There are also variations in availability, so that the com-

⁴ Progress in Biological Inquiries, 1938, pp. 43-47.

mercial fishery probably reflects fluctuations in abundance more or less imperfectly, depending on whether fishing conditions are favorable or unfavorable. For these reasons the recognition of an irreversible decline in abundance is not easy, but requires evidence on many aspects of the fish and the fishery.

During the season of 1938-39 the exploitation of the fishery was modified by withdrawal, in midseason, of floating reduction plants from high-seas operation. This action was the result of economic difficulties during the early part of the season and of the previous year, and coincided with the passage, by referendum, of an amendment to the State Constitution giving the California State Fish and Game Commission authority to prevent deliveries by California fishing boats to establishments outside of the jurisdiction of that State.

The season's catch was as follows: California, 574,676 tons; Oregon, 17,018 tons; Washington, 26,483 tons; British Columbia, 52,049 tons; a grand total of 670,226 tons. Of this quantity, 44,000 tons were caught for floating reduction plants operating on the high seas off San Francisco.

The total was more than 37.3 percent higher than that of the previous season. This increase probably may be ascribed to a natural fluctuation in abundance brought about by the entrance into the fishery of unusually successful year-classes produced some years previously; probably in 1934 to 1936. This probability is suggested by the higher percentage of young fish in the catch. It is difficult to determine, however, from present evidence, whether the increase is due altogether to these incoming year-classes, or partly to a better availability than obtained the previous season. An apparent dearth of older fish also raises the question as to the possible existence of a fundamental decline obscured by the accession of so many young.

The program of work discussed herein was carried out by a staff consisting of O. E. Sette, who was in charge of the investigation, Dr. L. A. Walford, Kenneth Mosher, Ralph Silliman, Earle Palmer, and Robert Luckhardt. The broad scope of the investigation and its accomplishments were possible only because of the cooperation and assistance of several organizations and persons. Clerical and technical assistance were furnished by W. P. A. Projects 702-3-1 and 10917; thus, 10,000 scales and a like number of otoliths were mounted, 550 bottles of plankton were sorted, and extensive statistical processes were carried on which would not otherwise have been possible. The extensive plankton research was made possible by the cooperation and collaboration of the Scripps Institution of Oceanography and its director, Dr. H. U. Sverdrup. Subsequent studies on hydrographic data carried on by Mr. Richard Tibby, of that institution, were made available immediately to the Bureau for its biological studies of the young pilchard. The California State Fisheries Laboratory, the Fish Commission of Oregon, the Department of Fisheries of Washington, and the Fishery Research Board of Canada all contributed records essential to various phases of the Bureau work of 1938-39. Stanford University contributed laboratories for the central office, and also provided facilities in Hopkins Marine Station for the Bureau field man stationed at Monterey. Members of the faculty of Stanford University, notably Drs. Frank W. Weymouth and Willis H. Rich, contributed advice on matters pertaining to the Bureau program.

STUDIES OF ABUNDANCE

According to a study of the catches of a fleet of purse seiners which were delivered primarily to reduction ships on the high seas off the coast of central California, the abundance of pilchards in that area has undergone a fluctuation; increasing slightly less than twofold from the season of 1932-33 to that of 1934-35. During the succeeding 3 seasons it decreased by about 70 percent, and in the last year, 1938-39, it increased again by about 15 percent.

An essentially similar course has been demonstrated by the study conducted by the California State Fisheries Laboratory on the shore landings at the ports of Monterey and San Pedro. Therefore, it was evidently a condition effective generally in the waters off California. Obviously, the initial rise during this period was due to the entrance of a successful year-class, or group of year-classes, probably 2 in number, produced in the spawning seasons of 1930 and 1931. The subsequent downward trend in the curve, a matter of 30 percent per annum, represents the decline of a population dominated by these 2 year-classes, to which there were no important new accessions. By itself, 30 percent per annum has little significance, but must be compared either with a previous or a future cycle of the passage of a successful year-class or group of year-classes through the fishery. Unfortunately, the manner of regulating the fishery in previous years, enforced in part by the State and in part by the industry, makes it difficult to obtain a parallel statistic for previous comparable cycles. However, judging from the high percentage of the young, coupled with the large catch of the current season, it appears that a new cycle has now begun and will soon afford the desired comparison.

In Washington and Oregon the fishery for pilchards has a history too short to cover the same period as that studied for California. The available records, as analyzed by Vernon E. Brock, of the Oregon Fish Commission, in collaboration with O. E. Sette, pertaining to the summers of 1935 to 1938, inclusive, did not show a decline similar to that noted from the California records, but rather an oscillation about the horizontal trend; the years 1935 and 1937 being high, and the years 1936 and 1938 being low. This is a somewhat surprising result in view of the finding by both British Columbia and California investigators that pilchard migrate between California and British Columbia waters. Hence, fluctuations should be similar, even at these extremes of the range, provided the entire population migrates. The only inference to be drawn from the lack of similarity in the results from the north and south is either that a varying proportion of pilchard migrates to northern waters each summer, or that availability in the north fluctuates so strongly that the commercial fishery cannot reflect changes in general abundance. A longer series of observations must be awaited before conclusions on these points can be reached.

AGE AND GROWTH

The identification of year-classes, and the measurement of their relative strength, involves a knowledge of past survival rates of young fish, which can become known by determining the age of fish

surviving to commercial size. Though an approximate knowledge of age and growth has been attained through a study of the size composition of the commercial catch, a greater precision is necessary for determining the relative numbers of each year-class surviving from year to year; and, also, the relative mortality rates, once the fish attain commercial size. Such precision is possible by determining the age composition of the commercial catch. Age determination is a technically difficult task, having been first attempted some 14 years ago, and, up to the time of this investigation, not yet accomplished. By intensive experiments during the past 2 years it has been found that the age of juvenile pilchards, i. e., those up through the third year of life, can be determined by rings formed annually on the scales and also on the otoliths. It was found that in California, fish of the year among the samples studied in 1938 had a modal body (standard) length of about 70 mm. (total length of about 3.3 in.) in June, when they first appeared in the bait fishery, and grew to about 120 mm. (total length of about 5.6 in.) by the following April, by which time the first annual mark had formed. At that time the modal length of fish having 2 marks was about 165 mm. (total length of about 7.7 in.), and of those having 3 marks, around 195 mm. (total length of about 9.1 in.). Though the study has been concerned only with young fish, it has, by defining age marks and proving their annual occurrence, made way for a similar study of the scales of older fish. Of these, there are 2 groups: Young adults usually caught during the fall months, and older adults caught in northern waters during the summer and in California waters during the winter. During 1939 an extensive collection was made of the scales of both groups from Grays Harbor, Wash., and from Monterey, Calif. A preliminary examination of the scale samples gives promise of success in determining the age of commercial-sized fish.

SAMPLING

Sampling of the commercial catch was carried on in California at San Pedro, Monterey, and San Francisco shore plants by the California State Fisheries Laboratory; at floating reduction plants operating off San Francisco and at Grays Harbor, Washington, by the U. S. Bureau of Fisheries; at Astoria by the Oregon Fish Commission; and at British Columbia by the Fisheries Research Board of Canada. Preliminary study of these samples, and of those taken in California in each of the preceding 20 years by the California State Fisheries Laboratory, indicates that the pilchard population is by no means distributed at random and that a simple summation of samples, however intensively taken, cannot be expected to represent fairly the population. Apparently the fishery draws on a succession of "runs" in each locality. These runs vary in their duration, and differ significantly with reference to the size and the abundance of fish composing them. These variations are probably connected with peculiarities in hydrographic conditions which change during the season, and from season to season. For example, a set of hydrographic conditions conducive to catching small fish for a relatively long period of time in one season, as compared with another set of conditions which permit fish of that size to be caught during a short

period of another season, will cause overrepresentation of the small size in the one season as compared with the other. During 1938-39 a method of weighting the samples to eliminate part of the distortion has been devised. Unfortunately, that method results in each run being given equal weight, and, though it is perhaps an improvement over an unweighted series, it still does not represent the relative abundance of the various sizes because the relative abundance of the fish in the various runs is not taken into account. A method of treatment which will accomplish the desired results remains to be discovered. Until then, our information on the relative strength of year-classes in the commercial fishery, the rate at which they have been consumed by natural and fishing mortality, in short, the condition of the resource, can only be understood imperfectly.

EARLY LIFE HISTORY

It has been reported⁵ that there is some relationship between temperature and successful survival. As yet it is unknown whether it is the temperature alone that governs survival, or whether it is other things associated with temperature, for example, ocean circulation. To investigate further the factors related to survival, a preliminary oceanographic survey of the waters off California, Oregon, and Lower California was carried on during the spring and early summer, when 90 stations were occupied; some of them as much as 320 miles offshore. The Scripps Institution of Oceanography cooperated by taking serial temperatures, making salinity and oxygen determinations, and phytoplankton and zooplankton hauls at all stations visited. The Institution is now studying the hydrographic data to elucidate the system of currents.

The Bureau's collections of fish eggs and larvae at the same stations will afford knowledge of the relationship between the distribution of young stages of pilchard and the various water masses in the circulation pattern. Off central, southern, and Lower California, substantial numbers of young stages of the pilchard were found well offshore in a band lying 125-175 miles off Monterey, 75-125 miles off San Pedro, and 75 miles off Ensenada. Thus the bulk of the planktonic stages were taken well outside the range in which most of the commercial fish are caught prior to the spawning season, indicating that the fish largely go offshore to spawn. No stations were occupied off northern California, owing to rough weather. A few eggs were taken at widely scattered stations off the Oregon coast, although not enough of them were obtained to define their zone of distribution. The survey off Oregon was made rather early in the season, possibly before the climax of pilchard spawning had been reached, and conversely in southern and Lower California rather late in the season, undoubtedly after the climax of spawning had passed. It was impossible to reach all parts of the area in the limited amount of time with only one boat. It is probable that the stations visited off central California were occupied near the time of the spawning peak in that locality. If so, the amount of spawning there was substantially less than in southern California.

⁵ Progress in Biological Inquiries, 1938.

To arrive at a more definite knowledge of the distribution of spawning requires simultaneous operation of several research boats, so that stations could be more closely spaced and visited a number of times during the spring and summer. The importance of such simultaneous surveys cannot be overestimated, for this is the most direct means, possibly the only one, of determining whether the spawning stock is being maintained at a sufficiently high level to provide adequate replacement for a large and intensive fishery. The possibility of a concerted oceanographic program would be greatly enhanced were a Bureau research boat available to participate with other agencies that maintain research boats in this region.

CONDITION OF THE RESOURCE

It is apparent from the foregoing that present information concerning the pilchard is imperfect, and that nothing final can be said relative to the exact status of its stock. Nevertheless, a number of observations already made indicate strongly that the present large commercial fishery is producing its effect. Prior to the season of 1937-38, fishermen in California always were able to supply as much fish as processors could accept, and often more. During this period the total catch rose at a logarithmic rate (i.e., at an equal percentage per annum), increasing 14 percent per annum, or, roughly, doubling every 5 years. In 1937-38, however, for the first time, the supply failed to meet the demand, in spite of a rise in price from \$10 to \$13 per ton. This situation could mean that during the preceding years the size of the stock had declined; it could signify that the availability of the fish changed abruptly that season; or it could indicate that the demand had outgrown the ability of the fishermen to supply pilchards at a price economically in line with other competitive raw materials. It could also mean, and probably does mean, that a combination of these three causes was effective. In any case, it is likely that further expansions of the industry might not be economically sound, regardless of whether or not there was an actual decline of pilchards in the sea.

A further apparent effort of exploitation in California, first observed during the season of 1937-38, is the occurrence in the catch of an unusually large proportion of small fish, or, conversely, a low proportion of large fish. This might, and probably does, signify that recent years had produced unusually successful year classes. If the large fish, however, were fully as abundant as formerly, then the addition of these quantities of small fish should have increased the abundance markedly, and the catch per boat should have risen by the season of 1938-39 substantially more than the observed 15 percent. Available information suggests that the population of older fish had been reduced more than had been offset by the accessions of young fish in 1938-39, although the current season of 1939-40 promises to constitute a more marked recovery.

In Oregon and Washington, it is difficult to appraise the condition of the pilchard resource; first, because the industry there is so young; and second, because of the suspicion that a varying proportion of the population of old adults migrate annually to the north to be caught in the fishery. It is fairly certain, however, that the abundance of

pilchards visiting Oregon and Washington waters must be limited by the size of the stock of old adults left after the much larger California fishery has taken its toll.

The evidence of exploitation discussed above, though subject to some uncertainties, taken together, indicate that the pilchard industry has reached maturity. By this is meant that it has arrived at a point where further expansion can result only in a rise of production cost. The industry is also at a point where it is likely to feel the effect of fluctuations in natural abundance more than it has in the past. It may even have overexpanded to the extent where the present level of total catch cannot be indefinitely maintained. If so, the effect of this situation may be that the successful year-classes, which occur as a rule only once in several years, will not persist long enough to last until succeeding successful year-classes appear. During such interims the industry will suffer for lack of raw material and this effect would probably be apparent rather soon. A second effect to be expected, theoretically, would not be so readily or so quickly apparent; i. e., a reduction in the spawning population to the point where so few eggs would be spawned that, even under conditions favorable for survival, the successful year-classes would not be so large as formerly. Thus, the fishery would have, over a long period, a downward trend, and would face not only a sharply fluctuating supply, but fluctuations at an increasingly lower level.

GREAT LAKES FISHERY INVESTIGATIONS

DR. JOHN VAN OOSTEN, *in charge*

The Great Lakes staff, under the direction of Dr. John Van Oosten, in 1939 as in 1938, devoted its attention largely to the continuation or completion of projects already under way. Ten publications appeared in 1939, and 4 papers, totalling 380 manuscript pages, are now in the hands of the printer. Several other reports are complete or nearing completion. Field work during the year was limited to a brief preliminary survey of the sport and commercial fisheries of Grand Traverse Bay, Lake Michigan.

One of the most significant events of the year was the revision of the commercial fishing regulations for the State of Wisconsin waters of Lake Michigan in October 1939, which constituted another important step toward the attainment of uniform regulations for all waters of that lake. The executive order, which was issued under the provisions of Wisconsin's discretionary power act, will, if enforced, bring the regulations for the Lake Michigan waters of that State as to size limits, mesh sizes, and closed seasons substantially in agreement with the State of Michigan regulations. Although a majority of the commercial operators previously had agreed to accept the provisions of the order, certain fishermen obtained a temporary injunction to prevent the conservation department from enforcing the new regulations. It is anticipated that the case will reach the State Supreme Court for final settlement.

On the whole, the past has been marked by an increasing interest on the part of the general public in the welfare of the Great Lakes fisheries. Newspapers in the Great Lakes region, and sportsmen's journals, have repeatedly carried articles calling attention to the

critical depletion of the commercial species and pointing out the need for adequate and uniform fishery regulations in Great Lakes waters. A similar interest in the Great Lakes fisheries was demonstrated by the resolution passed at the National Convention of the Izaak Walton League of America commending the Council of State Governments for its efforts to obtain the negotiation of a treaty with the Dominion of Canada for the establishment of an international board of inquiry "to the end that uniform regulations may be secured" in Great Lakes waters.

The rapidly increasing popularity of sport fishing in Great Lakes waters, with the consequent growing demand for the protection of game-fish species, and for the closure of certain waters to commercial fishing, bids fair to give rise to administrative problems of major importance. It is recognized generally that the monetary returns to Great Lakes communities for fish taken by tourists are far greater than the returns for an equal quantity of fish produced in the commercial fishery. It is economically expedient, therefore, to encourage the greatest possible development of sport fisheries and to provide adequate protection for game fish in those localities in which sport fisheries become established. On the other hand, it is unsound to place undue restrictions on the commercial fishery, particularly on the fishery for rough fish and other species of no interest to sportsmen. The indiscriminate closure of bays and other water areas to commercial fishing may provide valuable protection to game fish, but at the same time it may deprive local communities of revenues from commercial operations that could have been carried on without the slightest harm to the stock of game species. Unfortunately many sportsmen do not understand this situation. As a result, State legislatures are subjected continually to heavy pressure from sportsmen's organizations which seek to have this region or that region of the Great Lakes closed to all commercial fishing. Some extremely productive waters have already been closed when a few minor restrictions on commercial fishing operations would have been fully adequate for the protection of the game-fish species.

If the unwarranted closure of Great Lakes waters to commercial fishing is to be avoided, and if certain areas already closed are to be reopened, it will be necessary to obtain extensive factual data on the relationship between the sport fisheries and the commercial fisheries of the Great Lakes, and with this information to convince all concerned that there is no important conflict between the best interests of the sport and commercial fisheries.

Experience has demonstrated the special importance of preventing the development of antagonism on the part of the public toward the fishing industry. A bitter but valuable lesson on this point was obtained in connection with the closure, by act of the Michigan Legislature, of Potagamissing Bay in northern Lake Huron. Although an impartial survey conducted cooperatively by the Bureau and the Michigan Department of Conservation demonstrated conclusively that the commercial fishery in the bay was not harmful in any important degree to the stock of smallmouth black bass, and that only limited restrictions on commercial operations would provide that species with almost complete protection, the sport fishermen nevertheless insisted upon and obtained the complete closure of the waters under dispute.

In order to better acquaint sport fishermen with the true relationship between the sport and commercial fisheries, and to prevent a repetition of the misunderstanding that occurred in connection with the Potagannissing Bay controversy, Dr. Van Oosten has, within the past 2 years, accepted a number of invitations to speak before sportsmen's organizations in the Great Lakes area. He has agreed also to cooperate in an advisory capacity with the Michigan Department of Conservation in a survey of the sport and commercial fisheries of Grand Traverse Bay, Lake Michigan, the leading center of the "deep-sea" trolling fishery for lake trout.

The appointment of Dr. Van Oosten on Feb. 2, 1939, to the Water Resources Committee (of the National Resources Committee) for the Lake Ontario-St. Lawrence-Champlain Basins, gives the Bureau representation on the basin committees for the entire Great Lakes region. Dr. Van Oosten previously had been made a member of the Upper Great Lakes—Superior, Michigan, and Huron—and the Lake Erie Basin Committees.

The long-established policy of full cooperation with other agencies, particularly the State departments of conservation, was continued through 1939. Dr. Van Oosten attended 12 meetings and conferences at which Great Lakes fishery problems were considered, and with others was directly instrumental in obtaining the Governor's signature to the executive order containing revisions of the Wisconsin fisheries code. Five presentations of the moving picture, "Great Lakes Fisheries Investigations," were made before groups of scientists and sportsmen.

FISHERY STATISTICS

The completion of the analysis of the 1938 commercial fisheries statistics for the State of Michigan waters of the Great Lakes under the direction of Dr. Ralph Hile, made available detailed information covering a 10-year period on the fluctuations in the production and abundance of important commercial species, and in the intensity of the fishery in each of the 21 statistical districts into which the State of Michigan waters have been divided. The pronounced decline in the production and abundance of whitefish in Lake Huron constituted the outstanding feature of the 1938 data. The production of only 558,000 pounds was the second lowest on record and was only a little more than one-eighth of the record productions of 1931 and 1932. The abundance index for whitefish in 1938 was only 29 percent of the 1929-34 average. The decline of the Lake Huron whitefish has been, in large measure, due to the overproduction made possible by the use of the extremely efficient deep trap net. Although the deep-trap-net fishery was investigated thoroughly by the Bureau and the Michigan Department of Conservation in 1931 and 1932, and regulations for its control suggested in the latter year, effective laws restricting the use of this gear were not forthcoming until the whitefish stock of Lake Huron suffered serious, possibly irreparable, damage.

RED LAKES INVESTIGATION

In response to repeated requests by the Commissioner of Indian Affairs, addressed to the Commissioner of Fisheries, Drs. John Van Oosten and Hilary J. Deason made a brief survey of the fisheries and

fisheries resources of the Red Lakes during the period Aug. 23 to Sept. 10, 1938. The commercial fisheries of the Red Lakes, first begun in the fall of 1917, constitute one of the principal sources of livelihood of the Red Lake Indians who, since 1929, have marketed their catches through their own cooperative under the supervision of the Superintendent of the reservation. Regulations for the conduct of the fisheries are promulgated by the Commissioner of Indian Affairs, United States Department of the Interior. Frequent controversies over the regulations and criticisms of the methods of conducting the fisheries, as well as assertions that the Red Lakes were becoming depleted, led to the need for an investigation of the various problems in order to find some means for their solution. The biological data, statistical records, and historical and documentary information accumulated during the course of the survey have been studied and embodied in a formal report that is approaching completion.

The statistics of the annual production of the Red Lakes fisheries yield no positive evidence of a decline. The observance of an arbitrarily assigned maximum production limit of 650,000 pounds per year of the most desirable varieties appears to provide insurance against overexploitation of the stock. The catches per unit of fishing effort in the Red Lakes compare favorably with the catches per unit of effort in some of the best fishing areas of Lakes Michigan and Huron.

The growth of the wall-eyed pike (*Stizostedion vitreum vitreum*) is slower in Lower Red Lake than in Lake Erie, Lake Champlain, or Lake of the Woods, but is superior to the growth of the same species in Lakes Nipigon and Abitibi (Ontario). The relatively slow growth of the Lower Red Lake wall-eyed pike is compensated to some extent by its heavy stature, since the coefficient of condition, K , for wall-eyed pike was higher than for any population for which such data have been obtained. There is no basis for the assertion that the wall-eyed pike of Lower Red Lake are inferior to other populations for commercial purposes because of their slenderness. The Red Lake wall-eyed pike reaches the size limit of 14 inches, fork length (about 15 inches, total length), during the fifth year of life. The commercial catches consisted principally of members of age-groups IV and V. Studies of the percentage maturity at different lengths revealed that the 14-inch size limit (fork length) is adequate to permit the majority of females to spawn at least once before they reach commercial size.

The yellow perch (*Perca flavescens*) of Lower Red Lake grows more slowly than the perch of Lake Erie and Nebish Lake (northern Wisconsin), but more rapidly than the perch of two other northern Wisconsin lakes. As was true of the wall-eyed pike, the yellow perch of Lower Red Lake had a higher average value of the coefficient of condition than any other perch population for which data are available. The commercial catch of yellow perch was composed, in the main, of members of age groups V to VII, with age group VI predominating. Perch of younger ages and of smaller size could be taken with profit and without danger of depleting the stock. However, the gill-net mesh used in the Red Lakes must remain adjusted to the more abundant and commercially valuable wall-eyed pike, and therefore the most efficient utilization of the perch population cannot be

effected. The continued use of a gill-net mesh of no smaller than 3½ inches appears to be an adequate safeguard against depletion of the yellow perch.

The whitefish (*Coregonus clupeaformis*) of the Red Lakes, judging from the meager data available, grows at an intermediate rate compared with seven other North American populations. The Red Lakes whitefish had a larger coefficient of condition than the whitefish of Lakes Huron and Champlain. The growth of the goldeye (*Amphiodon alosoides*) compared favorably with the growth of the species in lakes of the Prairie Provinces of Canada; fish of some age groups averaged larger, and some smaller, in Lower Red Lake than in the Canadian lakes. The sheepshead (*Aplodinotus grunniens*) of the Red Lakes grew slightly slower but had a higher average coefficient of condition than the sheepshead of Lake Erie.

Records of the artificial propagation of Red Lakes wall-eyed pike and whitefish and the stocking of other waters at the expense of the Red Lakes have been assembled and considered with a view toward recommending a future policy of artificial propagation. A more definite mesh size for gill nets, and the adoption of the flexible rule as the official method of measuring nets, will be included among the final recommendations. Additional matters related to a future policy for the Red Lakes fisheries also are being considered.

MIGRATION OF LAKE MICHIGAN FISHES

The results of extensive tagging experiments on Lake Michigan fish, conducted between June 1929 and August 1931 by Smith Bros., commercial fishermen of Port Washington, Wis., are contained in a joint publication (in press) by Mr. Oliver H. Smith and Dr. John Van Oosten. The project resulted entirely from the interest and initiative of the late Lester Smith and of Oliver H. Smith, who jointly defrayed all expenses—an unparalleled undertaking among Great Lakes fishermen.

Of the 2,902 Lake Michigan fish tagged and released, 48.8 percent were lake trout, 20.4 percent lake herring, 15.7 percent whitefish, 5.1 percent rainbow trout, 4.2 percent yellow perch, 3.6 percent lake chubs, and 2.2 percent were other commercial species. A total of 388 fish, or 13.4 percent of the total number tagged, was recaptured. The percentages of returns for the lake trout, whitefish, and sturgeon indicate a tremendous fishing intensity in Lake Michigan. Four of the five tagged sturgeon were recovered. It was estimated that more than 31 percent of the baby lake trout (12.8 in.) and more than 44 percent of the young whitefish (11.8 in.) later entered the commercial nets. About 28 percent of the lake trout recovered were legal in size, and about 14 percent of the recaptured whitefish were of legal length. About 51 percent of the recovered fish were taken within 10 miles from Port Washington, the port of tagging, and 81 percent were taken within a radius of 25 miles from that port. Lake trout, rainbow trout, and sturgeon were found to be extensive travelers; lake herring, whitefish, chubs, pilots, and perhaps perch, did not migrate so extensively. Lake trout, herring, and whitefish tended to move in a northerly direction, perch in a southerly, and rainbow trout in an easterly direction toward the Michigan shore. Sturgeon apparently roam all over the lake.

Fifty-three percent of the recovered lake trout were recaptured within 1 year of release; 73 percent within 25 miles from Port Washington. It required 3 years for the trout to become fairly well scattered throughout the lake. With the attainment of adulthood lake trout moved in all directions from the port of release, although nearly 50 percent of the adults were retaken within 25 miles from this port.

Data are given on the growth and estimated age of the tagged lake trout, rainbow trout, whitefish, and sturgeon. It was found that the minimum size limits of lake trout and whitefish on the Great Lakes are economically unsound—they are too low—because they permit the capture of these species at the time of the most rapid increase in weight.

AGE AND GROWTH STUDIES

Saginaw Bay yellow perch.—A study of the age and growth of the yellow perch, *Perca flavescens* (Mitchill), of Saginaw Bay, by Dr. Ralph Hile and Mr. Frank W. Jobes, has been completed and the first draft of the report prepared. Age determinations and computations of individual growth histories were made from the examination and measurement of the scales of 820 individuals collected in 1929 and 1930. The investigation of the length-weight relationship was based on data from 1,483 specimens, and the ratio between total length and standard length was determined from measurements of 1,411 fish. The report contains also a review of the statistics of the commercial production of perch in Saginaw Bay in the years 1891–1908 and 1916–38. The average annual production in the years 1917–38 has been only 28 percent of the 1891–1916 normal.

The method of calculating growth from scale measurements, based on a study of the relationship between body lengths and the lengths (radii) of “key,” or selected scales from 512 fish, resembled that employed earlier for the calculation of the growth of the Lake Erie perch. The use of direct-proportion calculations was found to be valid for all calculated lengths above 101 mm. Calculated lengths of 101 mm. and less had to be corrected (from an empirical curve of the body-scale relationship) to compensate the disproportionate growth of body and scale in small fish. Both sexes of the Saginaw Bay perch attain the legal length of 8½ in. during the fourth year of life, just as they are entering on the period of most rapid growth in weight. Growth of females is slightly more rapid than males, both in length and in weight. The length-weight relationship (sexes combined) was described by the equation, $W=0.9826 \times 10^5 L^{3.2174}$, where W =weight in grams and L =standard length in millimeters. The ratio of standard length to total length was found to increase with the increase in the length of the fish.

The Lake Michigan kiyi.—The kiyi, *Leucichthys kiyi* Koelz, is one of two species of chubs inhabiting the deepest waters of Lake Michigan that practicably may be exploited with gill nets. During the Lake Michigan investigation of 1930–32, scale samples, accompanied by data on length, weight, sex, and stage of maturity, were collected from 1,516 individuals. The scale samples, along with other data obtained during an analysis of the catches of experimental gill nets

of various sizes of mesh, have been employed for a study of the life history of the kiwi by Drs. Deason and Hile. The bulk of the scale material has now been studied. Growth rate is very rapid during the first year for fish in all parts of the lake, and averages about 100 mm. The increment during the second year is less than half of the first-year increment, and the growth rate decreases perceptibly during each of the later years of life. There appears to be an inverse relationship between latitude and the rate of growth. A slightly more rapid growth is indicated for the females than for the males. The scale collections, obtained from unassorted samples of the commercial catches of different sizes of mesh, between $2\frac{3}{8}$ and $2\frac{3}{4}$ in., stretched measure, consisted of members of age-groups II to VIII. The best represented age groups were III, IV, and V. The report will include also data on bathymetric distribution and on the occurrence of the kiwi in the different regions of Lake Michigan.

COOPERATIVE INVESTIGATIONS OF WISCONSIN LAKES

The Bureau continued to cooperate with the Wisconsin Geological and Natural History Survey in their limnological and fishery investigations of the lakes of northeastern Wisconsin by providing a small amount of financial assistance. Those investigations, conducted under the direction of Drs. E. A. Birge and Chancey Juday, are concerned with the study of long-term problems of theoretical and applied limnology and fishery biology.

Materials collected during the course of the cooperative investigations, 1930-32, during which time Dr. Ralph Hile, of the Bureau, was assigned to that work, have formed the basis for two fish papers, both of which are now in press.

Bathymetric distribution of fish.—Records of fishing operations with gill nets were employed by Drs. Hile and Juday in a study of the vertical distribution of fish in summer in five northeastern Wisconsin lakes. Comparisons of data for different lakes revealed that the depth of water inhabited by a single species varies rather widely from one lake to another: that the relationship between size of fish and depth of water inhabited varies from lake to lake; and that different species that live at the same depths in one lake may inhabit different depths in another. The variations in the bathymetric distribution of fish exhibited no clear-cut correlation with differences in temperature and the concentration of dissolved oxygen and free carbon dioxide. This lack of correlation was not taken as evidence that temperature and the concentration of dissolved gases are of little importance in determining the bathymetric distribution, but rather that other, undetermined factors may obscure the effects of physical-chemical conditions.

Growth of the rock bass.—The study by Dr. Hile of the growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in northeastern Wisconsin placed emphasis on the problem of annual fluctuations in growth rate and the strength of year-classes. The growth rate of the Nebish Lake rock bass varied from a maximum of 20.6 percent above average in 1931, to a minimum of 15.2 percent below average in 1928. The year-classes ranged in strength from the phenomenally rich

1923 year-class, which as age-group VIII made up 45.8 percent of the 1931 collection, to the extremely weak 1927 year-class, which as age-groups III to V contributed only 1.7 to 5.9 percent of the total collections of 1930-32. In general, strong year-classes occurred in years of good growth—in the second and later years of life—and weak year-classes were produced in years of poor growth. Peculiarly enough, first-year growth and the strength of the year-classes exhibited no correlation.

The analysis of the annual fluctuations in growth rate, and the strength of the year-classes of the Nebish Lake rock bass in relation to meteorological conditions, showed good growth to be correlated with high temperatures in June and September, and heavy rainfall in June. It was suggested that annual variations in temperatures in June and September may produce variations in the length of the growing season. The correlation between June precipitation and growth may depend on the enrichment of the waters of this extremely oligotrophic lake by materials washed in during periods of heavy downpour. Substances added in June may be more fully available for utilization than those introduced in other months. Strong year-classes were correlated with high temperatures and heavy precipitation in early season, with conditions in June especially significant. High temperatures and an enrichment of the lake by run-off water may produce favorable feeding conditions for small rock bass at a critical period of their life history.

Comparisons of the data for the Nebish Lake rock bass with similar data for stocks from neighboring lakes suggest that to some extent the effects of meteorological conditions on different populations may be similar. For example, the 1923 year-class of rock bass was exceptionally strong in Muskellunge Lake and Trout Lake, as well as in Nebish Lake. Furthermore, good growth of rock bass and high temperatures, especially in June, were correlated in Muskellunge Lake, and apparently in Silver Lake. On the other hand, a number of discrepancies suggested that conditions peculiar to the individual lakes at times may modify or obscure the effects of the weather on growth rate and the strength of year-classes. There was some evidence also that the growth rate and the survival of young in different calendar years may be affected by fluctuations in the density of the population.

Progress during 1939.—A study of the growth of the bluegill, *Lepomis macrochirus* Rafinesque, of Muskellunge Lake, has been completed and submitted for publication by Dr. Clarence L. Schloemer, who has also made progress with an investigation of the life history of the wall-eyed pike, *Stizostedion vitreum vitreum* (Mitchill), in Wisconsin waters, and a paper on methods of determining the magnitude of fish populations. Mr. David G. Frey has nearly completed his work on problems related to the carp, *Cyprinus carpio* Linnaeus, in Wisconsin lakes, and continued a creel census on Lakes Waubesa and Kegonsa. Mr. Willard A. Van Engel terminated a study of the growth of the northern pike, *Esox lucius* Linnaeus, in Wisconsin waters, and undertook an investigation of the black crappie, *Pomoxis sparoides* (Lacépède), which will be continued for 3 or 4 additional seasons. Dr. Schloemer and Messrs. Frey and Van Engel are members of the staff of the Wisconsin Geological and Natural History Survey.

SHELLFISH INVESTIGATIONS

DR. PAUL S. GALTSOFF, *in charge*

In accordance with the previously adopted program of the Bureau's shellfish investigations, the research on oysters was conducted during the past calendar year with the following objectives: (1) To increase our technical knowledge regarding the methods of propagation of oysters under various conditions of the coastal waters; (2) to find practical means of improving the quality of marketable oysters; (3) to improve the methods of protection of oysters against various pests and parasites; and (4) to determine the deleterious effects of pollution and to devise methods of rendering certain trade wastes harmless to oysters. Since the accumulation of technical knowledge remains useless until the findings of the experts are brought to the attention of interested persons, considerable effort was made to disseminate the acquired information by preparing memoranda and pamphlets containing summaries of the most recent investigations, and distributing them among the oyster growers.

In compliance with the request of the local oystermen, the Bureau's station at Milford, Conn., continued throughout the summer of 1939 to issue weekly bulletins containing information concerning the condition of oyster gonads and the expected time of setting, and supplied detailed data concerning the distribution of starfish in Long Island Sound. Although these bulletins contained only local information pertaining to a small area along the Connecticut shore of the Sound, demands for them were received from oystermen operating in the States of New York, Rhode Island, and Massachusetts.

As in the past, the Bureau's investigations were greatly facilitated through the cooperation of the following organizations: W. P. A., P. W. A., N. Y. A., Connecticut Shell Fish Commission, Virginia Commission of Fisheries, William and Mary College, North Carolina Fish Commission, South Carolina State Board of Fisheries, Beaufort County Commissioners, and Florida Department of Conservation.

Oyster-fishery studies were conducted at the Bureau of Fisheries Laboratories at Woods Hole, Mass.; Milford, Conn.; Yorktown, Va.; Beaufort, N. C., and Pensacola, Fla. Temporary headquarters for oyster-farming investigations were established also at Beaufort, S. C.

In compliance with the requests of the United States War Department, Corps of Engineers, special surveys were made of the oyster bottoms in the upper part of Buzzards Bay, and in Narragansett Bay, for the purpose of determining the effect of dredging operations on oysters. In cooperation with the Bureau of Construction and Repair, United States Navy, special observations on the fouling of ships' bottoms were conducted at Langley Field, Va., and at the Bureau's stations at Milford, Conn., and Pensacola, Fla.

OYSTER-CULTURE STUDIES

Woods Hole.—Laboratory studies of the factors controlling the spawning of oysters, conducted for a number of summers by Dr. Galtsoff at the Woods Hole Station, were completed and the results of the findings, summarized in three technical papers, were pub-

lished in the Biological Bulletin, Vols. 74, 75, and 78. It has been demonstrated by this investigation that an old concept of a single critical temperature that induces spawning in oysters is no longer tenable. Depending on the physiological state of ripeness, the oyster may spawn at various temperatures between 63° and 95° F. A thermic stimulus alone often is not sufficient to induce spawning, and a combined action of temperature and chemical stimulation are necessary to produce the desired effect. However, a number of chemical compounds were found to be effective in inducing spawning of the male oyster.

These physiological studies provide a key to a practical method of controlling the spawning of oysters under natural conditions. To speed up the discharge of spawn, ripe oysters from deep bottoms should be brought into shallow, warm water of the inshore areas and left there for a few days. Additional stimulus can be provided by opening a few ripe oysters, mincing their meats in sea water, and scattering this mixture over the bed of spawners. The method was tried with success by some of the oyster growers of Long Island Sound and in British Columbia.

Since it has been demonstrated that the proximity of both sexes is essential for a successful spawning of oysters, it would be expected that a considerable disparity in the sex ratio may interfere with their propagation. Previous field observations have demonstrated the prevalence of females among the adult oysters on certain oyster bottoms. An investigation of the problem, initiated by Dr. Galtsoff in 1937 and continued through the present year, showed that the increase in the female population is primarily due to the sex change among adult oysters. Continuing this study during the present fiscal year, 200 individually marked oysters, which were kept at Woods Hole and Milford, were retested for spawning. An analysis of the records obtained during the 3 consecutive summers shows that sex change among adult oysters occurs in both directions; i. e., from male to female as well as from female to male. It is interesting to note, however, that during the 3-year period 17.6 percent of the oysters under observation changed from female to male, as compared with 31.2 percent changes from male to female. Thus it is obvious that in spite of the change of a certain number of females to males, the proportion of females in the oyster population steadily increases with age.

From these data it is apparent that the maintenance of a more or less normal sex ratio is essential for successful propagation of oysters. For practical purposes, the problem can be solved by adding each year a sufficient number of 3-year-old oysters to the stock of old spawners.

A study of sex reversal in adult oysters is being continued with the view of determining genetic and environmental factors which control these changes.

Long Island Sound.—Observations on the development of gonads, spawning, setting, and mortality of oysters were continued by Dr. Victor L. Loosanoff and James B. Engle, of the Bureau of Fisheries Laboratory, Milford, Conn. The area under investigation, extending for about 30 miles from Bridgeport Harbor to Morgan Point, east of New Haven, represents the largest and most important part of

the Connecticut seed-oyster producing section. The methods employed in this study were the same as those used during the 2 previous years.

The development of gonads was followed since May 18, 1939, by making weekly inspection trips over the entire area under observation. By June 23, the average thickness of the gonad layer of oysters was about 2.8 mm., somewhat less than during the corresponding period of 1938 (3.3 mm.) and considerably below that of 1937 (4.3 mm.). From June 23 to June 28 the gonads increased to 3.1 mm. By this time many of the oysters were completely ripe, and some of them already had partially discharged their spawn. Two days later, partially spawned animals were found at almost all stations, and the average thickness of gonad layer decreased to 2.7 mm. Oysters from comparatively shallow areas were the first to spawn. Spawning soon began to be of more general occurrence, and on June 30 some oysters with partially discharged gonads were found at almost all depths ranging from mean low-water mark to 40 feet. As in the previous year, the temperature of water prior to and during the early period of spawning was several degrees below 20.0° C.

Systematic observations on the setting of oysters were made at 10 stations at Stratford Point, and 6 stations at Welchs Point. Additional weekly observations were made at 15 other stations located in different sections of the Connecticut oyster-growing area. The first light set of the year was recorded at Stratford Point on and around July 17, 1939, about 2 weeks after the first general spawning, at depths ranging from mean low water to 50 feet. Between July 20 and 24 the intensity of setting increased considerably, but decreased sharply after July 31. There was no setting between August 3 and 17. From then on until September 21, scattered and very light sets took place at medium depths and in shallow areas. Observations were continued until the first part of October but no new spat were found after September 21.

In the Welchs Point area the first setting occurred between July 18 and 21, and the last set was recorded on September 12. The peak of setting took place between July 25 and August 1. During that period setting was exceedingly heavy, especially at 30-foot depth, sometimes averaging over 380 spat per shell. In some samples, shells containing as many as 1,000 spat were found. After August 1 the intensity of setting sharply declined for the rest of the season.

Setting of oysters in 1939 was probably the heaviest since 1930, and certainly much heavier than in 1937 and 1938, although the quantity of spawn developed in 1939 was very small. This observation disproves the old idea that a good setting can be expected only in those years when the gonads develop large quantities of spawn. Of special interest is the observation that in 1939 the spawning and heavy setting of oysters took place during a period of prolonged and very severe drought. Prior to and during that period the river discharge, as well as the amount of precipitation, was exceedingly low. Considering the fact that setting in 1939 was much heavier than in many previous years, the question naturally arises whether the inflow of fresh water carrying certain substances is really important in inducing the setting of larvae.

North Carolina.—Experimental studies of the growth, reproduction and survival of oysters at different tidal levels were continued at the Beaufort, N. C., Laboratory, under the direction of Dr. Herbert F. Prytherch. The purpose of this investigation is to obtain the essential information required for improved cultivation of oysters on the extensive tidal flats of this region. Though conditions above low-water level are unusually favorable for growth, the oysters produced in this zone are of inferior quality because of the overcrowding resulting from prolific natural reproduction. Biological studies show that oysters in this region have two heavy spawning and setting periods; in June and September. The late set usually completely covers the first set, which is attached to the shells and other cultch scattered over the tidal flats. The chief problem, therefore, in producing oysters of good marketable size and quality on these areas, is to find a method of preventing "fouling" of cultch during the summer season. The principal lines of investigation undertaken were to determine the following: (1) The growth of seed and adult oysters at different tidal levels; (2) the intensity of oyster setting or other fouling of these oysters in relation to their vertical position; (3) the possibilities of controlling fouling by shifting of oysters in special holding devices to favorable depths during the spawning season, and (4) the value of specially constructed salt-marsh ponds and canals for intensive cultivation of oysters where control of depth, current velocity, and other factors is possible.

Four hundred oysters, 1 and 2 years of age, were attached to cement panels and studied with respect to growth in weight, volume, length, and width in relation to their position above and below low-water level. Additional records were kept of a series of 180 oysters, which were studied individually during the previous year to determine the effect of orientation on growth. Three series of panels were placed under the main pier in Beaufort Harbor, using the same arrangements described for the experiments in 1938. Four other series of 100 oysters each were placed at levels just above and below mean low-water mark in the improved marsh ponds and canals constructed adjacent to the laboratory. The unit panel employed in these experiments consisted of a reenforced slab of "Incor" cement, $34 \times 3 \times \frac{3}{4}$ in., to which the oysters were fastened with a detachable cement.

The general results of the entire series of experiments may be briefly summarized as follows: (1) In this region the most rapid growing level for oysters is found in the tidal zone extending from approximately 6 in. below low-water level to 12 in. above. (2) When seed oysters (year-old size) are placed in this zone they will reach good marketable size in 2 years and show an increase in volume ranging from 750 to 1,200 percent, and in weight from 860 to over 1,000 percent. (3) The essential conditions required for attaining this growth are a good circulation of water, ample space for expansion, exposure to air for short periods, and protection from overcrowding and smothering by other marine organisms. (4) The greatest increases in weight and size were obtained in the groups of seed oysters that were held in a vertical position with the hinge uppermost. Less than 10 percent of these oysters died during the 2-year period of experimentation. (5) The growth of oysters in North Carolina waters is most rapid during the late fall, winter, and early spring, and apparently

is associated with the more favorable conditions at that time for the growth of marine plant life.

Experiments in the improved marsh ponds and canals demonstrated that it was possible to utilize such areas for growing and maturing oysters because the attachment of spawn could be prevented by regulating the depth of water and velocity of currents. On adjacent outside beds the oysters had become "wrapped up" with spat by fall, while those in the ponds at the same level were free to continue their growth to a good marketable size. Even in experiments using the poorest type of seed from "coon" oyster beds, a growth in volume of over 300 percent was obtained the first year, and a long, fairly wide type of marketable oyster, for shucking purposes, developed. The seed oysters which were held on cement panels and in special trays showed an increase in volume of over 200 percent from August through December and were rapidly forming round, scalloped shells of the most desirable type. By holding seed in these devices it was possible in the experimental canals to cultivate oysters at concentrations equivalent to over 2,000 bushels per acre, regardless of the nature of the bottom. In general, the experiments indicate that the expensive procedure of cultivating oysters in controllable tidal bays and canals is practical because of the more favorable circumstances for protection and harvesting of the crop, and primarily because a high yield of better quality oysters may be secured. These experiments are being continued and developed on a small commercial scale in order to determine the maximum size and age attainable by oysters in these waters and the percentage of mortality to be expected according to age and environmental conditions.

South Carolina.—The experimental oyster farm established by the Bureau near Beaufort, S. C., late in 1938 has now been in operation for a full year, and considerable information respecting the problems of utilizing various types of bottom for seed production has been accumulated by Robert O. Smith, in charge of this investigation.

Distinctive conditions existing in the brackish waters of South Carolina and Georgia have long presented special problems to oyster growers. This section of the South Atlantic coast is unique in three major respects: (1) There is as much as 10 feet difference between high and low tide; (2), the great majority of natural oyster beds occur between tide lines; and (3), setting is so abundant that single seed oysters are difficult to obtain.

Under these conditions it is imperative that the oyster grower be provided with means for determining the relative value of various types of bottom for seed production, growth, and fattening of oysters for market. The cost of leasing bottom from the State is relatively high, making it economically unsound to lease sections which will be unproductive. At the same time practical methods of obtaining good seed at low cost must be found, and, in the case of market oysters, means of fattening them early, despite high water temperature, are desirable.

Using colored labor provided by a W. P. A. project sponsored by Beaufort County, and with the active cooperation of the South Carolina Board of Fisheries, about 25 acres in a representative creek are being devoted to oyster-cultural problems on a small commercial scale. Three creeks have been reserved by the State Board of Fish-

eries for Bureau use in experimental oyster farming, but present facilities are sufficient for operating only one.

During this first year emphasis has been placed on seed production. As a means of standardizing results, cultch material consisted exclusively of 60,000 bushels of clean oyster shells, made available from a local cannery, which were planted for catching spat and hardening the bottom.

Toward the end of the year 5 mud and shell dams were constructed to impound an area of about 25 acres of marsh, 5 acres of which are being utilized for growth studies of seed oysters. One thousand bushels of seed from the 1939 stock have been transplanted to this location.

Briefly summarized, the first year's work has provided data on the following subjects: (1) Daily hydrographic observations were made of the bottom water temperature, salinity, pH, and turbidity. (2) Although the water temperature reached 20.0° C. by the end of March, the oyster-setting season was observed to extend from the end of May to the first of November. Shell-bag collectors were found to be unsuitable for local waters due to the very slow rate of spat attachment. (3) The rate of growth of spat was determined during their first 6 months by measuring samples twice a month. A few early spat had reached 3 in. in length at the end of 6 months. (4) The relative value of various types of bottom for collecting seed was shown by actual production. A total of about 4,000 bushels of seed oysters was produced on the experimental area in Horse Pen Creek this year. (5) The existing belief that setting of oysters in South Carolina waters occurs only between tide lines was disproved. Oyster larvae readily set below low-water mark if clean cultch is provided. However, less than 10 percent of spat survive as long as 6 weeks at such depths.

Gulf of Mexico.—Oyster production on the Gulf coast has been at a low level for a number of years, and markets have found it necessary or advantageous to import oysters from the Middle Atlantic coast to satisfy the demand. Almost all of the oysters harvested on the Gulf coast, with the exception of those produced on private grounds, chiefly in Louisiana, are taken from natural oyster bars, or reefs, which have been built up by the slow accretion of centuries. Otherwise, little private oyster culture is practiced, although the various States attempt to maintain the natural oyster bars by extensive planting of cultch and seed.

The following difficulties are faced by State organizations in their attempts to maintain a large, dependable production of oysters: (1) More oysters are harvested than the grounds should produce, with the result that the size as well as the quantity harvested has been reduced. (2) There frequently is considerable mortality due to freshets, or periods of very low salinity in oyster-producing bays, caused by heavy rains or melting snow inland. (3) Some mortality caused by predators or parasites, such as conchs, sporozoans, and other organisms. (4) The effect of such nonparasitic organisms as the boring clam (*Martesia*), which inhabits the shells of oysters, is not yet known but will be determined.

In order to solve some of the most serious problems of the oyster industry on the Gulf coast, the Bureau of Fisheries established a permanent laboratory near Pensacola, Fla., in 1937. For this pur-

pose the Bureau took possession of the abandoned Pensacola Quarantine Station and adapted it to the needs of the shellfish investigations, with the aid of W. P. A. funds. Construction work at the station is expected to be completed during 1940.

In carrying out scientific investigations, Dr. A. E. Hopkins, director of the station, has cooperated extensively with oystermen and with conservation departments of the Gulf Coast States in formulating programs for the development and maintenance of natural oyster grounds, and the creation of new grounds, by planting seed and shells. In Florida, especially, much progress has been made in projects of this kind with the assistance of the W. P. A. During the year, surveys were made of the oyster grounds of Mobile Bay, Ala., and connected waters, and cooperation was given to the Alabama Department of Conservation in promulgating regulations designed to restore the grounds to their former productivity.

An experimental study was planned to obtain exact data on the effect of variations in salinity on oysters. However, the work has been deferred pending completion of large outdoor concrete tanks where the experiments can be carried on under controlled conditions. Observations were made during the summer in East Pensacola Bay, where there was a large mortality during a period of low salinity. Counts of live oysters and the intact shells of those that had died recently showed a mortality of 90.3 percent. The mortality was difficult to understand, since the freshet condition lasted only about 3 weeks, and since the oyster grounds are so located that they are supplied with salt water from the Gulf at high tide. A study of the data available indicates that the mortality was the result of a combination of factors, one of which was low salinity. The oysters had been heavily infested with a sporozoan parasite, *Nematopsis ostrearum*, which appeared to render the oysters less resistant to handling or transplanting. Also, the period of low salinity occurred in August, immediately after the oysters had completely spawned out and their resistance was greatly lowered. It is probable that low salinity decreases the feeding activities of *Ostrea virginica*. Dr. Hopkins found the same relationship between reduced feeding activity and low salinity in *Ostrea gigas*. The problem of the effect of salinity on oysters will be thoroughly studied as soon as possible.

RESPIRATION OF THE OYSTER

During past years considerable information has been accumulated by the Bureau's investigators regarding the nutritive value of oysters from different sections of the coast, and regarding the seasonal fluctuations in the mineral, water, and glycogen content of oysters in Long Island Sound. There is no doubt that the good qualities of marketable oysters are determined by a high percentage of solids, high glycogen content, and the presence of sufficient amounts of metals such as calcium, iron, copper, and iodine—important in a well-balanced human diet. The importance of producing oysters of highest nutritive value is now being recognized by the majority of the leading oyster growers. The difficulty lies, however, in the fact that present observational data provide no clue to the methods or procedures by which oysters of desired qualities could be produced. Practical solution of this problem rests on fundamental knowledge of

the carbohydrate and metal metabolism of the oyster. Since all the activities of an organism, in the final analysis, depend on respiration, the study of the gaseous exchange of the oyster was expected to throw light on other features of its metabolism. During the summer of 1939, experiments along this line were carried out at Woods Hole by Dr. Galtsoff, with the assistance of George Mishtowt. The purpose of the experiments was to determine whether the increased iron content had any effect on the rate of respiration. Oysters, poor in iron, were kept in water with high iron content until a great deal of the metal had been assimilated in the animal tissues. The rates of oxygen consumption of these oysters before and at the end of the experiments were determined and compared.

The excess of iron in the tissues seems to slightly increase the oxygen consumption, although the results of the summer's experiments are complicated by the change in the organisms caused by spawning. There was a general decrease in the oxygen consumption after spawning which amounted to 22 percent in the control oysters, while in the "iron fed" oysters it averaged only 19.4 percent. There was an apparently significant difference between the change of the metabolic rates of the male and female oysters, which is probably determined by their sex. In both sexes the lowest metabolic rate was found to occur during the after-spawning period, which is characterized by the poorest condition of the oyster meat. It is planned to continue this investigation by carrying out tests during the various seasons of the year.

OYSTER PESTS AND PARASITES

In addition to the starfish and oyster drill, which devour large numbers of newly set oysters, two other molluscs, namely, *Anomia* and *Crepidula*, were found to be responsible for the mortality among spat in the Long Island area. As a rule, the setting of *Anomia* and *Crepidula* occur almost simultaneously with the setting of oysters. However, because of the much lower rate of growth of oysters, *Anomia* or *Crepidula* soon suffocate the spat by covering it with their shells.

However, heavy mortality among oyster spat cannot be attributed solely to their enemies such as starfish, drills, *Anomia* and *Crepidula*. The oyster set died in some areas where these enemies were not numerous enough to inflict heavy losses. It is quite probable that in some areas of Long Island Sound the mortality of spat was due to a disease or infestation by some unknown parasite.

Starfish setting.—The first setting of starfish in 1939 took place in Long Island Sound between July 13 and 17, and continued until September 11 with two distinct peaks in the intensity, the first between July 20 and 24, and the second between July 31 and August 3. The heaviest setting took place at the stations located at 30- and 40-foot depths. The numbers of starfish that set in 1939 were small, and even at the height of setting the young starfish rarely averaged two per shell. However, because of a very high rate of survival among recently set starfish, and because of their rapid growth, they soon became a serious menace.

Distribution of starfish.—In accordance with the practice established last year, semiannual surveys of the distribution of adult starfish in Long Island Sound were made in March and November. As compared

with the conditions existing in November 1938, the density of the starfish population in different areas of the Sound in March 1939 remained virtually the same. In general, starfish were rather scarce or entirely absent. Even in the most heavily infested area between Charles Island and Stratford Point they did not exceed 77 per sample. The majority of the samples contained from 1 to 5 starfish only. The second survey, made in November, revealed a tremendous increase in the starfish population throughout the entire growing section. From 25 to 100 times as many were found in November as were found in March. The majority of starfish were of the 1939 set. The large increase in the numbers of starfish compelled the oystermen to carry on a vigorous campaign of eradication. A new method, consisting of spreading lime over the infested areas, was put into general use and proved to be quite satisfactory. At present this method is being relied upon by many oyster-growing companies operating in Connecticut, New York, and Rhode Island waters.

Oyster drill.—During the last few years the common oyster drill (*Urosalpinx cinerea*) has become very numerous in the waters of Long Island Sound, where it destroys large numbers of oysters. Experiments conducted at Milford Laboratory by Mr. Engle showed that the period of feeding lasted from late May until late November in 1939, with the peak of activity between the middle of August and the middle of September. The voracity of drills was observed under laboratory conditions. Several young *Urosalpinx*, less than 30 days old and about 2 mm. long, were put in an aquarium with oyster spat ranging from 2 to 4 mm. in diameter. Within 15 days 2 drills destroyed 142 oysters. The deposition of drill egg cases began early in June, when the water temperature was about 16.0° C. (60.8° F.), and continued through October. The heaviest egg case laying occurred from the middle of July through the middle of August.

Boring clam.—Another problem which has been attacked by the staff of the Pensacola Laboratory is the boring clam, *Martesia*, which is common on many parts of the Gulf coast. This clam apparently enters the shell wall at a small size and enlarges the cavity it occupies as it grows larger. Nothing is known of its life history at yet, save that it is a lamellibranch, and presumably has a free-swimming larval stage. In Mississippi Sound, near Biloxi and Gulfport, the infestation has begun to assume serious proportions. Fifteen years ago Dr. Galtsoff, after a thorough survey, reported no boring clams in that region. Oystermen claim that they have appeared only in the last few years, and now, on some grounds, living oysters are so infested with the clams that the shells crumble under slight pressure. It is not unusual for an oyster about 3 inches long to have 100 or more boring clams occupying each of its valves. As the clams grow to about one-fourth inch in diameter they consume the shell, leaving little protection for the oyster living within. An investigation of the life history of the boring clam, its habits and tolerance of environmental factors, has been undertaken at the Pensacola Station.

Sporozoan parasite.—A long-continued investigation of the sporozoan parasite of the oyster carried on by Dr. Prytherch at Beaufort, N. C., has been completed. A detailed description of the development and microscopic structure of this pest is incorporated in the manuscript entitled "The life cycle and morphology of *Nematopsis ostrearum*, sp.

nov., a gregarine parasite of the mud crab" (to appear in the *Journal of Morphology*). A report is in preparation on the other phases of this work dealing with field observations of oyster mortalities in Southern waters, and the effect of the parasite on the functioning of the adductor muscle of the oyster.

EFFECT OF PULP-MILL POLLUTION ON OYSTERS

The York River Investigations, carried on by Dr. Walter A. Chipman, Jr., and Dr. H. N. Calderwood, have been concerned with the continued search for the chemical or chemicals present in the effluents from pulp mills that cause changes in the physiology of oysters. This information is of importance in the problem of eliminating pulp-mill pollution. Progress has been made in the elimination of some fractions as causative agents, and in acquiring some knowledge as to the nature of these physiologically active materials. The investigations have not as yet progressed to a point where the actual causative agents can be definitely identified. As during the previous year, the work has been carried out in cooperation with the Virginia Commission of Fisheries, through an allotment of funds. Additional laboratory and office space were provided free of charge by the College of William and Mary.

Studies made prior to 1939 showed that effluents that enter the York River from the pulp and paper mill at West Point are effective in reducing the rate at which water is pumped by oysters. It has also been shown that the effluent that has the most active physiological effect arises from the making of pulp, and contains cooking liquor, weak black liquor, soaps, and foam, in addition to the wash waters. The work during 1939 demonstrated that the physiological activity of sulfate soap has been due to the black liquor it contained, and that the foam is no more than a mixture of soaps and black liquor. Samples of black liquor from which the soaps had been removed still maintained their potency. Consequently, the work has been directed towards fractionation of weak black liquor. The physiologically active material of the weak black liquor has been separated through procedures involving precipitation, extraction, and selective solution.

Chemical investigations on weak black liquor samples are being continued, with the object of discovering whether or not there is any correlation between the alkalinity and volatile sulfide content and the variations in the effect of these samples on oysters. It is hoped that the further fractionation of the weak black liquor and the analytical analyses of these fractions will supply definite information on the chemical nature of the physiologically active material, and thus allow steps to be taken leading to elimination of this type of pollution.

A small group of studies were made this year at the request of the Naval Mine Depot at Yorktown, Va., to ascertain whether or not wash waters resulting from the purification of stored TNT would be harmful to oysters and clams if emptied into the York River. As a result of the tests made it was found that no harmful effects could be expected at the dilutions to be discharged.

SPONGE-FISHERY INVESTIGATIONS

DR. PAUL S. GALTISOFF, *in charge*

Early in December, 1938, a heavy mortality broke out among the commercial species of sponge (wool, velvet, grass, reef, yellow, and hardhead) on the natural banks in the waters of the Bahama Islands. At the request of the Colonial Secretary of the Bahamas, and with the consent of the U. S. Department of State, Dr. Galtsoff was detailed to Nassau, Bahamas, to collaborate with the British Department of Sponge Fisheries in conducting the necessary investigation of the cause of the mortality. This detail, which involved no expenditures on the part of the Government, continued from February 15 to April 7, 1939. During this brief period extensive hydrographical, chemical, and biological observations were made in the area of greatest mortality, near Andros Island, with additional observations on the Little Bahamas Bank and in the inshore waters around New Providence Island. Laboratory and field experiments were conducted at the same time at Nassau and the field station at Mastic Cay, Andros Island. The records of a spread of mortality over the natural and cultivated sponge beds of the Islands indicate that the sequence of infection was from east to west, following the trend of water movements within this area. Determinations of salinity, pH, dissolved oxygen, excess base, calcium, and analyses for phosphates, silicates, and heavy metals failed to disclose any factor which may have been responsible for the mortality. Microscopical examination revealed, however, the presence of fungal filaments in all diseased sponges. These filaments have not been found in healthy sponge tissues, nor in the remains of sponges which have been long dead. They are particularly abundant in the marginal zone between the newly dead and living tissues of diseased sponges. The infection spreads gradually through the tissues, starting often from an origin inside.

In the experiments conducted at Nassau, and at Mastic Cay, it was possible to infect reef and wool sponges with the fungus by contact with fragments of infected sponges of the same species. The fungus was tentatively identified as *Spongiophaga* sp. By the end of February the disease had spread to the northern coast of Cuba, and in March it was reported to have reached Key West, Fla.

A survey of the conditions of the Florida sponge fishery was made by Dr. Galtsoff immediately upon his return from the Bahamas. It was reported that during the first week of March large numbers of wool, yellow, and grass sponges were noticed on the reef extending along the Atlantic side of the Florida Keys. In a short time similar conditions were observed from Key West to Biscayne Bay. The mortality occurred almost simultaneously in Florida Bay, Barnes Sound, and Biscayne Bay, apparently spreading through the numerous passages which intersect the Keys and connect the waters of the Atlantic with those of the Gulf. Gradually the epidemic progressed westward over the entire area of Florida Bay as far as Cape Sable. Reports of the destruction of sponges in this region were received about the middle of April. At that time the mortality among commercial sponges reached such proportions that fishing became unprofitable, and had to be stopped long before the end of the season,

which usually lasts until August. It has been estimated that between 60 and 70 percent of the sheepswool sponges were destroyed and that yellow and grass sponges were almost completely wiped out. Reports from Cape Sable estimated about 80 percent mortality of sheepswool sponges.

Chemical and biological investigations established the striking similarity between the conditions found in the Bahamas and in the Key West area. There was nothing abnormal in the composition of sea water, plankton, and microplankton. On the other hand, microscopic examination of the diseased sponges showed the presence of a fungus morphologically identical with the microorganism found in the dying sponges of the West Indies.

During the spring, fishing in the Tarpon Springs area continued normally. None of the divers interviewed at that time reported any unusual conditions on sponge grounds. Rumors were persistent, however, of the presence of diseased sponges on some of the bars in the northeastern corner of the Gulf. Finally, one diver reported the presence of a large number of diseased sponges on the bars between Cedar Keys and Carabelle. Through the courtesy of Captain Maurice Gay, who offered free of charge the facilities of his boat, diving equipment, and the services of his crew, a survey was made of the affected area. Diseased sponges were found on the bars off Carabelle at the depths between 5 and 6 fathoms. The infection was light, however, and resulted only in a partial destruction of the sponge body. At the time of the investigation there was no pronounced mortality among these sponges. Because of lack of funds for sponge investigations field studies were discontinued, but arrangements were made with Captain Gay and the Florida Department of Conservation for collecting and preserving additional diseased sponges which were forwarded to the Woods Hole and Washington laboratories for microscopical examination. Throughout the summer and fall samples of diseased wool sponges were studied. A high percentage of them were found to be infected by fungus. In the meantime, reports received in the Washington office indicated the spread of the disease to the Tarpon Springs area. Increased mortality of commercial sponges on all deep-water grounds become so pronounced that in December fishing on bars situated below 8 fathoms was discontinued, and an unusually large number of sponge boats concentrated in a comparatively shallow area off Cedar Keys. At the end of the year, the number of sponges brought to the Tarpon Springs Sponge Exchange noticeably diminished, and the sponge fishermen and dealers were greatly concerned regarding their only means of livelihood. The future of this unique and highly specialized industry appears to be quite dark. Comprehensive plans for investigation and conservation of valuable sponge fishery resources have been prepared. Their execution depends, however, on the appropriation of necessary funds.

AQUICULTURAL INVESTIGATIONS

DR. H. S. DAVIS, *in charge*

The ever-increasing popularity of sport fishing has resulted in increased demands on our lakes and streams which can only be met by the development of scientific methods of fish conservation and man-

agement. While there is a limit to the production of fish in any body of water, it is probable that, in many cases at least, the yield of game fish can be materially increased. Investigations have shown that present methods of stocking and other practices often fail to produce the results expected, and it is evident that much remains to be done before fish management can be established on a sound basis.

These problems are being attacked along three principal lines. One deals primarily with the artificial propagation and rearing of game fishes; a second with the parasites and diseases of fish, especially those prevalent at hatcheries and which frequently seriously curtail the output; and a third line of investigation is concerned with field problems relating to fish management, such as comparative survival and growth of hatchery and wild fish under natural conditions, the ecological requirements of different species of game and food fishes, and the possibility of increasing fish production in natural waters.

In the interest of greater efficiency, the headquarters of the Aquicultural Investigations was moved to the experimental hatchery at Leetown (P. O. Kearneysville), W. Va., in the spring of 1939. This station, operated primarily for experimental work with both trout and warm-water fishes, also has adequate laboratory facilities, and hence affords an excellent opportunity for studies related to hatchery operations.

TROUT

Investigations on trout have been concerned chiefly with field studies of the results of artificial stocking and other problems related to fish management, with the development of cheaper and better diets for hatchery fish, and with selective breeding for the purpose of developing strains that are superior to those ordinarily found at hatcheries.

Feeding experiments.—Feeding experiments were continued at the Leetown Station by Dr. J. S. Gutsell. These experiments were designed primarily to develop better methods of feeding animal meals, since previous work had shown that these products, when combined with fresh meat, make an excellent and economical diet for trout. It was found that under ordinary conditions it is not advisable to use more than 50 percent dry meal in the diet. While trout can subsist on diets containing considerably larger amounts of meals, the meals are utilized less efficiently and there is considerably more waste in feeding. The rate of growth of trout on those diets is materially increased by the addition of small amounts of either cod-liver oil or kelp meal and is increased still further if both are included in the diet.

Experiments designed to show the effect of food on the quality of trout eggs have confirmed the belief of many fish-culturists that overfeeding is distinctly detrimental, since a larger percentage of the eggs fail to hatch. To produce eggs with the greatest hatchability, at the lowest cost, the fish should be fed a well-balanced diet in moderate amounts.

Experiments at Leetown, and at Hackettstown, N. J., in cooperation with the New Jersey Fish and Game Commission, have shown conclusively that frozen fish, when fed continuously in considerable

quantities, produce definite toxic effects. The trout become dark colored and eventually die.

Feeding and nutrition experiments conducted at the cooperative hatchery at Cortland, N. Y., are discussed in a separate section of this report.

Selective breeding.—Breeding experiments with brook trout were continued at the Pittsford (Vt.) Hatchery and have resulted in more than doubling the rate of growth and also the production of eggs. Strains of fish also have been developed that are more resistant to hatchery diseases, especially furunculosis.

Breeding experiments with rainbow trout are being carried on at the Leetown Station, but have not yet been continued long enough to produce significant results.

WARM-WATER FISHES

Studies on the black basses and other warm-water fishes are being conducted at the Leetown and Welaka (Fla.) stations. Hatchery and field investigations were carried on at both stations, but at Leetown the smallmouth black bass received most attention, while at Welaka the largemouth black bass was the center of interest.

Studies at Leetown.—The work on smallmouth bass streams in this region, under the direction of E. W. Surber, was confined to (1), the collection of 100 adult smallmouth black bass for food and parasite studies from each of the following streams: Cacapon River, South Branch of the Potomac River, and the Shenandoah River; and (2), the collection of temperature and turbidity records in the Shenandoah River.

Previous studies on the spawning of smallmouth bass in these streams have shown that large numbers are hatched each year, but that the number of young bass decreases rapidly a short time after they leave the nest. The loss is probably greater than in hatchery ponds under ordinary conditions. A large part of this loss in streams is believed to be due to predacious fish, especially young smallmouth bass in their second and third year of life. Some of the loss appears to be caused by parasitization.

Experimental work at Leetown has been limited, due to lack of suitable ponds. However, 28 new ponds, designed especially for experimental work, were completed during the past year and will be available for use in 1940. Some experiments with forage fish, carried on during 1939, demonstrated that when ponds are stocked heavily with black-head minnows before smallmouth bass fry are added, large numbers of fry disappear, presumably because they are eaten by the minnows. Largemouth bass fry, however, have a better chance of survival. The results indicate that 1,000 to 3,000 black-head minnows per acre can be used successfully if ponds are not stocked with minnows until the bass fry are too large to be eaten.

Studies at Welaka.—The work at this station is under the direction of O. Lloyd Meehan. During the season 1939 only 8 ponds were available for experiments, and were fertilized with cottonseed meal at weekly intervals. Four ponds were stocked with bream (bluegills) and golden shiners to serve as forage, and the remaining 4 ponds were stocked with largemouth black bass only. The ponds

that contained forage fish produced an average of 5,120 largemouth bass fingerlings per acre. The results, however, varied greatly in the different ponds, and indicate that much is still to be learned concerning the ecology of ponds that contain forage fish. In ponds where fertilizer alone was used the yield of bass fingerlings was much more uniform, with an average yield of 11,390 per acre.

In previous experiments in other localities Mr. Meehan found that in fertilized ponds, without forage fish, no matter how heavily the pond may be fertilized, the bass grow rapidly until they reach a length of 2.5 to 3 in., when growth practically stops. It was thought that if sufficient forage fish were present the bass fingerlings would continue to grow throughout the season, but this was not true. Growth was arrested at approximately the same time regardless of whether or not the ponds contained forage fish.

The largemouth black bass fry grew to a length of 2.5 in. in approximately 2 months. One pond was then drained and stocked a second time with largemouth bass fry, and yielded a total production of 19,047 2.5-in. fingerlings per acre for the season. After removal of the largemouth bass fingerlings the pond was stocked with bream (bluegills), which yielded 47,179 1.5-in. fingerlings per acre when drained in the fall. The total yield of this pond for the season was 66,227 largemouth bass and bream fingerlings, which is believed to be a record.

FIELD STUDIES

Fish management studies on trout waters were carried on at the Pittsford (Vt.) and Leetown (W. Va.) Stations, in the Pisgah Game Preserve in North Carolina, and in Utah, Idaho, and California.

Test waters.—The field work at the Pittsford Station, under R. F. Lord, has been confined to the so-called "test waters," which have been operated in cooperation with the Vermont Fish and Game Service. This work was begun in 1935 on Furnace Brook. The following year two more streams and Chittenden Reservoir were included in the program, increasing the number of test waters to four, the maximum number allowed by law. However, in 1939, two of the streams were discontinued as test waters and observations were made only on Furnace Brook and Chittenden Reservoir.

The total catch on Furnace Brook for the season of 1939 consisted of 1,321 brook trout and 1,676 rainbow trout, a total of 2,997 fish, as compared with a total catch of 4,647 in 1938. This was the lowest catch recorded since the study began, and was probably due, in large part at least, to the severe flood of September 1938, which did great damage to Vermont streams. It is interesting to note, however, that, as in 1938, the catch of rainbow trout exceeded that of brook trout, even though no rainbow trout have been planted in the stream for years, while it receives a heavy stocking of brook trout annually.

Artificial stocking appears to have given better results in Chittenden Reservoir, although the results are by no means conclusive, due to incomplete data. However, fishing in this lake has improved greatly since it has been stocked annually with large rainbow trout. An accurate count of marked fish captured by anglers was made on only a few days, and 27.5 percent of the fish taken were

hatchery reared. It is noteworthy that one-third of the marked fish were planted in 1937, the remaining two-thirds in 1938.

St. Mary River.—On the basis of observations made on the St. Mary River by Mr. Surber, from 1935 to 1939, it was concluded that the stream is well-suited to trout, so far as temperature and other physical and chemical conditions are concerned. The stream is rather poor in food, however, and an examination of the stomachs of 51 brook trout and rainbow trout showed a numerical predominance of terrestrial over aquatic insects. This was especially true of the brook trout. Rainbow trout consumed considerably greater numbers of aquatic forms, as well as considerable quantities of algae. Artificial stocking with brook and rainbow trout has had little effect on the fishing. Of 11,107 marked trout planted since 1935, only 268 or 2.4 percent have been recovered. The observations also revealed a very slow growth rate of stocked fish; a marked downstream migration of rainbow trout; an increase in the populations of both brook and rainbow trout due to natural propagation; and a gradual decrease in the numbers of planted rainbow and brook trout.

It is planned to continue the work on this stream during the coming year, and it has already been stocked with marked brook and rainbow trout fingerlings. North Creek, a stream of quite different type, also will be placed on an experimental basis next year. This stream is believed to provide much better conditions for trout, and will afford an excellent opportunity to determine whether or not rainbow trout will show a greater tendency to remain where planted when the environment is more suitable.

Pisgah Game Preserve.—The United States Forest Service has complete control of the wildlife on the Pisgah Game Preserve, and consequently the streams of this area afford an exceptional opportunity for experiments in fish management and for a demonstration of what can be accomplished by scientific methods. That the management program, under the direction of T. K. Chamberlain, is producing results is indicated by the fact that in 1939 it was possible to accommodate more anglers and permit a longer season than in previous years. In spite of the increases in total fishing intensity, the number of fish caught per angler was practically the same in 2 successive years, 4.8 in 1939, as compared with 4.9 in 1938. A cursory examination of the streams after the fishing season had closed indicated that many of them could have been fished more intensively without danger of depletion. In fact, some streams apparently are in danger of becoming overpopulated with trout, and therefore it is proposed to allow a material increase in the amount of fishing during 1940.

Since anglers are required to have their catches examined at checking stations, complete data are obtained on the species, size, and markings of all fish caught. However, no information can be obtained from this source concerning the migrations of fish within a particular drainage, or of trout below legal size. This, and other information which is not obtainable from an examination of anglers' creels, are essential for successful fish management. The required information can be procured most satisfactorily by sampling the fish population, but it is practically impossible to use a seine in the average trout stream. In an attempt to work out a satisfactory method for sampling our streams, the chemical method of conducting a fish census is being investigated.

Lake management studies in Ocala National Forest.—Field studies in Florida have been confined largely to the Ocala National Forest which affords exceptional opportunities for the investigation of lake-management problems, since there are a large number of lakes that may be opened or closed to fishing as necessity dictates. Surveys of these lakes have been carried out in cooperation with the Forest Service. A stocking program based on these surveys was initiated in the fall of 1939, under which all the important lakes within the area will be adequately stocked.

Certain immediate objectives have been set up for study and a group of 11 lakes has been set aside by the Forest Service, with the consent of the Florida Commission of Game and Fresh Water Fish. A second group of 8 lakes was closed to fishing in 1939 for the purpose of determining the fishing load which lakes of various food grades may be able to maintain with or without a stocking program.

In the study of fish populations it is planned to kill and examine fish of various food grades in lakes which have already been closed for scientific study. The value of this information lies in its application to all of the lakes in the area, and a more intelligent evaluation of their crop capacity.

Intermountain Region.—The work in this region is under the direction of Dr. Stillman Wright, who has devoted much of his time to an investigation of Bear Lake. This lake, which is situated almost equally in Utah and Idaho, at one time supported a large population of native trout. Marked depletion of the stock was noted as early as 1884, and presumably the decline has continued up to the present time. At a meeting of representatives of interested agencies at Pocatello, Idaho, in March 1939, it was agreed that each State would contribute \$600 to aid the Bureau in a biological survey of the lake to serve as a basis for a management plan. This amount was later increased to \$800 and 2 biologists spent the summer on the lake. The survey is being continued during the winter months by occasional visits to the lake, and will be carried on intensively during the summer of 1940, each State having contributed \$920 for the purpose.

The Bureau has continued to cooperate with the Utah Game Commission in the control of undesirable species of fish in Fish Lake. This lake is probably one of the most productive in the country, but recently there has been a marked decrease in the catch, especially of brook trout. It was thought that an important factor in the depletion might be the increased abundance of the Utah chub. Accordingly, great numbers of these fish were killed with rotenone (derris root). There is evidence that the condition of the brook trout improved following the reduction of the chub population in Fish Lake, and this fact is believed to justify a continuation of the program of chub control.

While most of Dr. Wright's activities were concerned with the Bear Lake and Fish Lake projects, some attention was given to a number of minor problems. An inquiry was made into the cause of an extensive mortality of whitefish in Lake Pend d'Orielle, Idaho, and 1 week was spent in Colorado investigating a number of fishery problems.

CALIFORNIA TROUT AND SALMON INVESTIGATIONS

The management problems now being investigated, under the direction of Dr. P. R. Needham, include three major phases: (1) Cooperative stream and lake surveys and catch record work with the United States Forest Service in California and Oregon; (2), operation of the Convict Creek experimental stream, near Bishop, Calif.; and (3), studies of salmon that will be prevented from migrating to their spawning grounds on the upper Sacramento River because of the Shasta Dam.

Cooperation with the Forest Service was curtailed, owing to lack of funds. However, stream and lake surveys were carried on in the Mount Hood and Fremont National Forests in Oregon, and the Whitman National Forest in Washington. Complete catch records were secured for a third angling season on Squaw Creek, in the Shasta National Forest, California. A report covering 3 seasons' work on this stream is now in preparation.

Mexican trout.—A second trip was made to Lower California to secure *Salmo nelsoni* to replace the first lot lost during the flood in March 1938. These trout, inhabiting the warm and isolated Rio Santo Domingo, were secured to try and develop a stock which will be tolerant of warm water and nonmigratory. The trip was highly successful, and 325 fingerlings between 2 and 4 inches long were transported by truck to the experimental stream near Bishop, without the loss of a single fish. Later they were transferred to the Clarkamas Hatchery, near Portland, Oreg.

Convict Creek experimental stream.—The season's work was begun on April 25. Construction of the large cabin begun in 1938 was completed, and a diversion ditch was excavated around the experimental area to by-pass excess water during spring floods.

Studies were again concerned with the problem of the survival of trout after planting. Winter conditions in this region permit only seasonal operation. In the season of 1937 the planting experiments were operated for a period of approximately 75 days; in 1938 this was extended to 90 days; and, in 1939, to 107 days.

A new experimental section over 800 feet in length was made available by the construction of a concrete flume screened at the upper and lower ends. All wild fish were removed from the section which was then stocked with 1.4-in. Loch Leven trout. The survival after 107 days was 87 percent, and the average length 2.64 in. In general, survival rates in 1939 were less than in 1938, which is surprising in view of the fact that the number of wild fish competing with the planted fish was greater in 1938. Survival records for 3 years have now been accumulated, but owing to limited personnel a thorough analysis of the data has been impossible.

A population study was made in two series of pools in Convict Creek—one below the experimental area in open waters, and one within the area where no fishing is permitted. It was found that the section open to angling contained 3.8 trout, 6 in. long, per pool, while in the closed section there were 14.5 trout per pool. While pools in the section open to angling contained fewer large trout, they contained larger numbers of fish of the younger age-groups than pools in the closed section. It is interesting that such

a short closed section (less than one-half mile) protects the large fish. Evidently they did not exhibit much movement during the summer.

Shasta Dam studies.—Surveys to determine the most feasible means of salvaging chinook salmon whose migration will be blocked by the Shasta Dam were continued on funds provided by the Bureau of Reclamation. These surveys showed that none of the tributaries of the Sacramento River below the dam site afford either spawning areas or suitable water for transference of the salmon.

In order to provide a suitable stream to which the salmon runs can be transferred, it is proposed to bring water by flume from the McCloud River to Stillwater Creek, and thus provide a permanent flow into this stream. Stillwater Creek rises in the foothills on the southern edge of the future reservoir and flows south about 24 miles to join the Sacramento River south of Redding. At present this stream has an intermittent flow and is dry during part of the summer and fall. Nevertheless, chinook salmon spawn in it naturally, and its gravel bed should provide excellent spawning grounds if a permanent flow is provided. The plan also includes a hatchery, with holding and rearing ponds, at the head of Stillwater Creek.

Counts of adult salmon that passed over the dam at Redding were continued during 1939. Between April 17 and December 9 a total of 21,897 chinook salmon were recorded. These counts do not include fish that ran in late fall, winter, or early spring, and it is estimated that the total run now passing the site of Shasta Dam is approximately 25,000 fish. A preliminary report on the entire Shasta Dam salvage problem is in preparation and will be completed early in 1940.

PARASITES AND DISEASES OF FISH

Increased facilities for pathological work at Seattle, Wash., have enabled Dr. Frederic F. Fish to carry on his work to much better advantage. His most important contribution during 1939 was the discovery that formalin is a most effective agent for the control of the external parasites of fish. In the formalin treatment, fish-culturists now have at their disposal a safe, practical, and economical method of eliminating ectoparasitic protozoans, and possibly other parasites as well. Heretofore the great limitation to prolonged treatments has been the lack of a disinfectant possessing a sufficiently large factor of safety between effective and lethal concentrations. Comparative tests with a protozoan parasite (*Trichodina* sp.) showed conclusively that formalin was far more effective than any other disinfectant used. Exposure of heavily infected fish to a 1:4,000 solution of formalin for 60 minutes resulted in complete elimination of the parasite, without injury to the fish.

However, prolonged treatments in the standing water of a fish pond, although simple, effective, and cheap, involves oxygen depletion and the accumulation of carbon dioxide. A comprehensive investigation of this problem is now under way, the ultimate objective being the preparation of a series of tables giving the time required to exhaust the dissolved oxygen to an arbitrary level of 4 p. p. m. under all normal hatchery conditions.

A second major investigation was the study of an epidemic of *Costia necatrix* at the Bureau's hatchery at Birdview, Wash., in

cooperation with the Division of Fish Culture. These studies indicate that *Costia* may be a forerunner, and probably a direct cause, of the Western type of gill disease. It is believed, however, that *Costia* is not the sole cause of this type of gill disease, which presumably may result from any prolonged irritation of the gill epithelium. Infection by *Costia* can be prevented by weekly treatments with a 1:6,000 solution of formalin.

During the past year an effort was made to place the losses that occur at the Bureau's trout hatcheries on an accurate statistical basis. Records, based insofar as possible upon actual counts of 288 lots of fish at 22 separate hatcheries, were analyzed for the percentage loss occurring among progressive size groups at half-inch intervals. The average loss between the eggs and 4-inch fingerlings was approximately 50 percent, which is much less than is believed to occur in nature. These results further emphasized the importance of hatchery losses and the need for more investigations of their causes. In 102 lots of fish, where both food and mortality records were available, it was found that the cost of food fed to these fish was \$5,732. The economic value of the dead fish among the 102 lots was conservatively estimated at \$35 817.

Several investigations of losses of fish at hatcheries in the general vicinity of Seattle, and losses among wild fish in the field, were made by Dr. Fish. Of the latter, losses among silver salmon, which apparently were caused by excessive sunshine, and attacks by fungus, (*Saprolegnia*), which inflicted serious losses among adult chinook salmon and steelhead trout liberated in the Entiat River in the Columbia River salvage operations at Rock Island, were most noteworthy.

At the Leetown Station, George E. Klak made a study of a strigoid worm which is very abundant in the black-head minnows. He found that these worms caused sterility when their number was in excess of 1,000 per fish. In some cases they occurred in such numbers as to rupture the abdominal wall.

Dr. Davis continued his studies on a suctorian parasite of the smallmouth black bass. This parasite occurs on the gills, and when very abundant may seriously injure the host and eventually cause its death. It does not affect the largemouth bass, even when in the same pond with heavily infected smallmouth bass.

Studies are also being carried on at Leetown on the common bacterial gill disease of trout. It has been found that this disease may also affect largemouth and smallmouth black bass and has caused serious mortality among both young and adult fish. Other parasites of bass and trout are being studied for the purpose of clearing up certain points in their life history and developing better methods of control.

The disease service, which was inaugurated 4 years ago to assist fish-culturists in the control of hatchery diseases, continued to be heavily patronized during the past year. This service has proved to be very popular and has been an important factor in reducing losses.

NUTRITION STUDIES AT THE CORTLAND HATCHERY

The experimental hatchery at Cortland, N. Y., is operated under a cooperative agreement between the New York Conservation De-

partment, Cornell University, and the United States Bureau of Fisheries. The principal members of the staff of the hatchery are C. M. McCay, Cornell University; A. V. Tunison and A. M. Phillips, New York Conservation Department; and C. R. Mitchell and E. O. Rodgers, Bureau of Fisheries. The investigations at Cortland are of two general classifications; the development of feeding mixtures and methods, and studies of the transformation of food within the body of the trout.

The utilization of carbohydrates.—The inclusion of carbohydrates, such as sugar and starch, in fish diets provides an opportunity for reducing feeding costs. The greater the percentage of carbohydrate materials that can be used by the fish, the cheaper the diet. If concentrated sources of carbohydrate material are to be used to replace meat proteins, the fish must be able to utilize them in the sugar or starch form in which they are administered. A series of experiments designed to study the rate of digestion and absorption of carbohydrates was conducted. Trout are able to digest and absorb large amounts of sucrose (cane sugar). Coating the sugar with melted tallow reduces the loss in water when fed in a meat mixture and the melted tallow also retards the rate of disappearance of the sucrose from the intestinal tract. The use of tallow introduced a fat complex into the study. The sucrose was administered in gelatine capsules inserted directly into the digestive tract by means of a fine forceps. Brook trout weighing from 6 to 14 g. were used in the studies. The capsule usually is penetrated in about 1 hour and the sugar starts to dissolve in the gastric fluid. When the trout were killed immediately after feeding, from 96 to 100 percent of the sugar was recovered from the digestive tract. At the end of 3 hours the sucrose had disappeared from the capsule entirely.

Sucrose was administered in 10-, 25-, and 50-mg. feedings, placed in capsules. The experiments, in which brook trout were killed at various intervals of from 3 to 72 hours after feeding, showed that the amount of sucrose absorbed was dependent on the amount available in the gastro-intestinal tract. No sucrose was found after 72 hours, indicating that absorption is practically complete by that time.

Effect of diets on the liver.—Brook trout fed diets rich in cooked starch, sugar, or dextrin, developed large livers that contained a high percentage of glycogen. Those fed raw starch or cellulose, instead of cooked starch, sugar, or dextrin, developed livers comparable in size and glycogen content to the livers of brook trout fed meat alone. An analysis of the livers of trout fed diets containing various carbohydrates was made in terms of percentage of total body weight constituted by the liver, percentage of dry matter in the liver, percentage of dry protein in the liver, percentage of fat in dry liver and milligrams of glycogen per gram of fresh liver.

Experiments on staining bones in vitro.—In experimental stream studies, and in some nutritional studies, it would be a great aid if fish could be marked by some ingredient introduced into the hatchery diet. Since the staining of bones in the growing fish might be developed into a method of marking large numbers of fish, preliminary experiments were conducted. Madder root in the diet in a proportion of 0.5 part per hundred had produced no results at the end of 12 weeks, when the madder content of the diet was increased to 15

parts per hundred. Then the vertebrae assumed no color but the rib bones became definitely pinkish. At the end of 20 weeks the rib bones retained little color but the mandible had a distinct pink color. Since the size of the bone may have some effect on the absorption of madder, the experiments are to be continued. Purified chemicals and other brands of madder root also will be tried.

Growth of three strains of brook trout.—Growth studies were conducted using 3 strains of brook trout, 2 from commercial trout hatcheries and 1 from the Bureau's Craig Brook (Me.) Station. They were fed the same diet, similar amounts of food in terms of percentage of the body weight, and were held in troughs at the same weight per cubic foot of water. Although the fry did not start to feed at the same time, during a period of 32 weeks, the growth curves for each strain were surprisingly similar. The average percentage gain in weight by 4-week periods for the entire duration of the experiment was approximately the same for each population.

Source of protein as a factor in growth.—Protein is the most costly nutrient of the diet and may be derived from either plant or animal tissues. Diets were compared that consisted of 50 percent pig spleen, 2 percent salt and raw starch, and various percentages of the following ingredients, individually and in combination: Dried skim milk, cottonseed meal, whitefish meal, and wheat flour middlings. The amounts of the ingredients were so adjusted that in combination with the pig spleen the total protein content of each diet was 29 percent. The greatest and an almost equal percentage gain in weight was obtained by the use of the three diets that contained dried skim milk, whitefish meal, or a combination of the four ingredients, in addition to the pig spleen, salt, and raw starch. The diets that contained cottonseed meal and wheat-flour middlings as the variable source of protein gave results somewhat inferior to the other three diets, but which were practically identical.

Comparative growth of six groups of trout.—To improve the technique for conducting feeding experiments, and to determine the probable variability between troughs, similar diets were fed to 6 groups of brook trout during a period of 24 weeks. Only 1 group of the 6 showed a statistically significant difference from the mean growth of all 6 groups. The growth during the first 12 weeks averaged 36 to 39 percent; during the second 12 weeks, 18 to 22 percent; and during the entire 24-week period, 28 to 31 percent.

Assay method for "Factor H."—In order to develop an assay method for "Factor H," brook-trout fingerlings were fed a synthetic diet of raw corn starch, dextrin, casein, yeast, mineral mixture, and cod-liver oil for a period of 4 weeks when the accelerated condition of mortality indicated Factor H depletion. The group was divided into 12 lots, and each lot was placed in a separate trough. Three lots were fed the same diet. The various diets contained 10 percent, 15 percent, and 20 percent beef liver in addition to the synthetic diet, and the synthetic diet alone.

After 2 weeks, 40 percent of the fish fed on the synthetic diet alone had died. The remainder were then fed 100 percent beef liver. At the end of 16 weeks the fish on the all-liver diet had stopped drying and had resumed normal growth. The inclusion of only a percentage of beef liver in the diet failed to arrest mortality.

Different results, however, were obtained with each diet. The conclusion was reached that the diet must include in excess of 20 percent fresh meat in order to revive brook trout after they have suffered Factor H depletion.

Factor H depletion was accompanied by a decreased erythrocyte count, and led to the production of severe anemia. The addition of beef liver to the synthetic diet caused an increase in the red-cell content of the blood. A count of red blood cells may provide an indication of the presence of anemia, even before the onset of heavy mortality.

The effect of diet on condition.—The condition factor of brook trout, which is an index of the relative heaviness of a fish, in terms of a mathematical expression, increases with the length. Trout of the same size fed on the same diet show little variation in condition. The value of the condition factor showed a positive relationship to the protein content of the diet.

Protein requirements of trout.—Experiments conducted by Dr. McCay and associates, in 1931, proved that the protein requirements of trout was 14 percent or slightly higher. The experiments were resumed in 1939 to define more precisely the protein requirements of growing trout. Groups of trout were fed diets that contained 5, 10, 12, and 16 percent protein for 24 weeks. The trout were weighed periodically during the course of the experiment and showed the following average gains in weight for 4-week periods: 5 percent protein, 7 percent gain; 10 percent protein, 17 percent gain; 12 percent protein, 20 percent gain; and 16 percent protein, 29 percent gain. The mortality decreased as the percentage of protein was increased. With a diet containing 5 percent protein, 9 percent was converted into body protein; a 10 percent diet resulted in the conversion of 15 percent; a 12 percent diet gave 17 percent conversion; and a 16 percent protein diet resulted in 22 percent conversion.

Practical diets.—Experiments were conducted to test and compare the cost and efficiency of diets for practical use. Mixtures of dry foods bound together with salted spleen were tested. The diet considered most useful consists of equal parts of dried skim milk, cottonseed meal, wheat-flour middlings and fish meal combined with 4 percent of their weight of salt and an equal weight of ground frozen spleen. Diets that contained salmon-egg meal and seal meal produced considerable mortality, accompanied by a slimy condition of the body and a gill disease. Until more is known of the toxicity of salmon-egg meal and seal meal they should not be used in fish diets.

INVESTIGATIONS IN INTERIOR WATERS

DR. M. M. ELLIS, *in charge*

Pollution studies.—The pollution studies of the Bureau have been centered at the University of Missouri, at Columbia, where a generous provision of laboratory space and other facilities has been made. A portion of the investigations has been conducted at a subsidiary laboratory located at Fort Worth, Tex. The pollution problems throughout the United States, both specific and general, are so manifold that their permanent solution necessitates a continuation of a program of laboratory research designed to analyze thoroughly the

cause-effect complex that is involved in every type of situation. Because immediate and epidemic situations are frequently of a transient nature, the research program is more concerned with an analysis of the cumulative physiological effects of pollutants related to the fish themselves than with the application of palliatives. The investigational program also attempts to determine the precise agent or agents in pollution situations that are responsible for deleterious effects on the fish populations and their habitat.

Three major lines of investigations organized in 1938 were carried forward in 1939 by the Columbia, Mo., field unit in conjunction with the laboratories at Columbia, and at Fort Worth.

Analytical studies.—Waters, muds, and aquatic organisms collected in the field are sent to the central laboratory for detailed analyses, which are carried out by Dr. B. A. Westfall and his assistants. In addition to the materials collected by the staff, in the course of field work, a large number of samples are sent in for examination by the various State agencies.

Bioassays.—As during previous years, the specific effects of materials found in waters, muds, and pollutants, on living fish, and other aquatic animals, were determined by the bioassay method. The bioassays of pollutants sent to the Columbia unit, by State authorities and other agencies, have become an important function of the laboratory, and many determinations are constantly in progress.

Physiological investigations.—The underlying causes for the actions of the various substances found in natural waters and pollutants on living fish are sought through studies of the physiology of fish conducted under the direct supervision of Dr. Ellis at the Columbia and Fort Worth laboratories. As in 1938, one of the major fields of physiological investigation during 1939 was a study of the effects of various components of larvacides and herbicides on fresh-water fishes, and their associated aquatic food organisms. Because the biochemical and physiological tests necessitate technique of considerable precision, each fish is maintained and studied separately and receives individual feeding and care, frequently for several months. More than 300 fish are constantly under observation at Columbia, and numbers of catfish, bass, and other fishes are under observation as part of this investigation at Fort Worth. These studies have progressed to the point where it is possible to conclude that there is impairment of the growth and nutrition of fishes in waters treated even with small quantities of arsenicals and several other materials commonly used as mosquito larvacides. A separate report on this subject has just been presented to the Malaria Control Committee as part of the cooperative program on mosquito-control measures conducted in the T. V. A. area.

Throughout the year physiological studies, with concurrent analyses, have been made on the effects of several substances dangerous to fish life which were found in natural waters in the West in the course of the field investigations, with particular reference to the natural pollution picked up by waters used for irrigation during their passage over fields and through irrigation ditches. Marked concentrations of various mineral salts have been discovered in many return irrigation waters, and the detrimental effects on fishes noted. Through the application of physiological, biochemical, and metabolic methods to the study of fishes from irrigation waters, it has been

established that many fish in such waters are definitely below par in general physiological condition and reproductive capacity. Irrigation, therefore, constitutes a major and growing hazard to fish life in many of our Western streams.

Utilizing these same methods, the studies of fishes from streams polluted by mine wastes have demonstrated chronic injuries to fishes resulting from much higher dilutions of the wastes than has heretofore been recognized. A detailed report on the effects of lead, gold, silver, arsenic, zinc, and copper mining is in preparation, based on the data obtained during these studies.

Summer field surveys.—During the summer of 1939 intensive studies of stream pollution were made along the Atlantic seaboard, and throughout the greater part of the Western United States, and considerable new information was collected on the nature and effects of polluted waters. Observations were made in the States of North Carolina, South Carolina, Florida, Texas, Arizona, Nevada, California, New Mexico, Oregon, Washington, Idaho, Wyoming, and Montana. Over 9,000 analyses were made in the field and additional material was returned to the laboratory at Columbia, Mo., for further analyses.

Early in the summer Dr. Ellis and a field party continued the field work in the headwaters of the Grand River in Oklahoma, Kansas, and Missouri, relative to the pollution of the Grand River impoundment which is being constructed near Vinita, Okla. This work was completed in the fall and a report submitted to the Grand River Authority, pointing out the hazards of the chatfields and other sources of pollution found in this area.

From Oklahoma the party continued south to Fort Worth for work on the catfish under observation at the Bureau of Fisheries' Fort Worth Station, thence to Medina Lake and Uvalde, Tex., where special studies of bass and Rio Grande perch are in progress.

On completion of this trip the field party visited North Carolina and worked southward through the coastwise streams to Florida for a series of paper-mill and phosphate-mine pollution studies. A stop was made at the Welaka (Fla.), Station, to obtain bass material to be used in connection with the studies of mosquito control.

Late in July the field party moved west through South Dakota, Montana, and Idaho on the mine-pollution problems, and gave particular attention to the Black Hills gold-mine pollution of the Belle Fourche River, the copper-mine pollution of Clarks Fork, in the vicinity of Deer Lodge, Mont., and the lead and zinc pollution of the Coeur d'Alene River in Idaho.

From Idaho the party proceeded to Mt. Rainier and Mt. Shasta for a continuation of glacial-water pollution studies which have been in progress there for 3 years, and to make specific checks of silt conditions which will contribute to the fishery problems in the Sacramento River following the construction of a new dam, now in progress near Redding, Calif.

From California the party returned via Lake Mead, central Utah, Arizona, and New Mexico, stopping at established stations in these States where stream-pollution studies from mines and irrigation are in progress.

Studies of impounded waters were continued at Elephant Butte Reservoir, in cooperation with the United States Reclamation Service and the National Research Council, and at Lake Mead in cooperation with the same agencies and the National Park Service.

HYDRAULIC SECTION

HARLAN B. HOLMES, *in charge*

For a number of years the Bureau of Fisheries has felt the need for a well-organized section in the Division of Scientific Inquiry in which the combination of biological and engineering talent could be applied to fish and fishery problems created by the construction of dams, reservoirs, and diversions for the purposes of power, irrigation, navigation, and flood control. The perpetuation of fish populations following the development of such projects requires a detailed analysis of the changes in biological and physical conditions, and of the biological requirements of the fish that inhabit the areas involved. As a general rule, the solution of those problems involves the construction of fishways to enable upstream migrants to pass over dams and other obstructions, and the installation of screens to prevent the entrance of downstream migrants into irrigation diversions and hydraulic turbines, in which they would be lost or injured.

For the study of these problems of fish protection, and the construction and operation of fishways, screens, and other protective works, there has been created within the Division of Scientific Inquiry a Hydraulic Section. Mr. Harlan B. Holmes has been appointed to the position of Aquatic Biologist, in charge, and Mr. Olaf W. Lindgren has been employed in the capacity of Associate Hydraulic Engineer. Funds for this section first became available in July 1938, but activities were not begun until late in the year when Mr. Lindgren entered the service. Mr. Holmes, who for a number of years has been loaned to the War Department, Corps of Engineers, in connection with fish problems at the Bonneville Dam, was not available to the Bureau of Fisheries until October 1939. Other members of the biological staff of the Seattle Laboratory have taken part in the work of fish protection.

The work of the Hydraulic Section during the year has included the partial construction of 4 large fish screens in Federal irrigation canals, the reconstruction of 2 existing screens, the operation of 6 screens throughout the irrigating season, aid in the study of fish problems in connection with the Shasta Dam Project, being constructed on the Sacramento River in California, and a preliminary study of fish problems in connection with many other Federal water projects. Consulting assistance in connection with fishway and screen problems also has been furnished to the conservation agencies of several States.

All of the screens operated by the Bureau of Fisheries were on Federal canals in the Yakima Valley; the Kittitas, Tieton, and Sunnyside canals on Bureau of Reclamation projects; and the Ahtanum, Old Indian, and Wapato canals operated by the Indian Service.

One of the screens reconstructed during the year is in the Pishkun Reservoir of the Sun River Project in Montana. It is a bar-type

stationary screen. As originally designed, it provided insufficient screen area when the water level in the reservoir was low. The screen also had become damaged by ice. It was reconstructed and modified to correct the difficulties.

ICHTHYOLOGICAL INVESTIGATIONS

Fishes collected in the Panama Canal.—Complete lists of the fishes collected in the locks of the Panama Canal in 1935 and 1937, together with discussions of the intermingling in the Canal of fresh- and brackish-water species from the opposite slopes of the Canal Zone, and the extensive invasion of fresh or nearly fresh water by marine fishes, are included in a recently published paper by Dr. Samuel F. Hildebrand, entitled "The Panama Canal as a passageway for fishes, with lists and remarks on the fishes and invertebrates observed." As indicated in the title, some invertebrates also are mentioned. Although many marine fishes enter and some pass through the locks, only one species, the tarpon, is known definitely to have completed the transit; in this case, from the Atlantic to the Pacific. Brackish- and fresh-water species from the opposite slopes intermingle freely.

Fishes of Tortugas, Fla.—A large monograph of the fishes of Tortugas, Fla., left unfinished by the late Prof. William H. Longley, was completed by Dr. Hildebrand. A total of 435 species are listed, 29 of which were discovered during the investigation. Much information of taxonomic importance was gained, and the knowledge of the life histories of many species was greatly extended, especially of the shallow-water forms which could be observed in their natural environment by the use of a diving hood.

American anchovies.—Taxonomic revisional studies of the American anchovies were continued by Dr. Hildebrand. Many interesting relationships, unrecognized species, and many misidentified specimens in various museum collections have been found. The numerous misidentified specimens in collections serve to show how imperfectly the species hitherto have been known.

Systematic studies.—Isaac Ginsburg continued his systematic studies of American fishes. Accounts were prepared of the genera *Enyphias*, *Barbulifer*, *Coryphopterus*, and *Parrella*. Material was gathered on the systematics of a number of other gobiid genera, with the object of preparing needed revisions. Population studies were made of some of the common species of *Microgobius*, *Lepidogobius*, and *Bathygobius*.

Population studies strike at the very root of one of the fundamental problems, not only of fishes, but of all biology, and that is the species problem. Offhand, this would hardly seem to be a problem. The layman, especially if he is of the observant type, seems to be able to distinguish well enough the comparatively few species of animals and plants with which he is familiar. The specialist, however, if he is a careful worker, sooner or later is confronted with the following questions: What is a species? What is a subspecies? What is a race? This is a real and fundamental problem in biology, about which a considerable degree of misapprehension exists, even among systematists. In connection with the population studies an attempt was made to reach down below the surface of the problem, and to evolve general principles and a method that will contribute

to its solution. A paper was published supplementing others that have previously been published, dealing with this problem. Another paper, treating of another phase of the question, has been prepared and is now in press. The problem also has an important practical bearing. In our work of conservation it is important to distinguish properly, and understand, the interrelationship of the populations that make up the economically important fishes.

INDEPENDENT ACTIVITIES OF THE BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

During the summer, the U. S. Fisheries Laboratory at Woods Hole served as headquarters to Dr. Paul S. Galtsoff, In Charge of Shellfish Investigations, and the acting director and his staff. The laboratory facilities of the station were also used by John R. Webster, of the Bureau's North Atlantic staff, for studying the effects of various types of tags on mackerel.

As in previous years, the privilege of occupying facilities in the laboratory at the Woods Hole Station was extended to a small number of private investigators. Following is a list of such persons and the problems of their research during their stay at Woods Hole: Dr. Hugh M. Smith, former U. S. Commissioner of Fisheries, taxonomic studies of local fishes; Dr. Joseph M. Odiorne, Colby College, behavior of melanophores of *Fundulus*; Dr. Rastum Maluf, Johns Hopkins University, osmoregulative mechanisms in crayfish; Dr. Raymond W. Root, College of the City of New York, effect of carbon dioxide on the respiratory function of marine fish blood; Dr. Henry Brown, College of the City of New York, assistant to Dr. Root; Dr. Bolton Davidheiser, Johns Hopkins University, the effects of X-ray on males of *Sciara*.

BEAUFORT, N. C.

Research facilities were provided throughout the year at the Beaufort Laboratory for biological studies of marine organisms and certain species of fish and shellfish of importance to the commercial fisheries of this region. During the summer season 28 investigators from other institutions conducted studies here in various fields of zoology. The chief investigations carried on by the Bureau's staff, under the direction of Dr. H. F. Prytherch, consisted of experiments in controlling the growth and reproduction of oysters; the utilization of improved marsh ponds and canals for intensive cultivation of clams and oysters, the propagation of diamond-back terrapin; and the rearing and live storage of certain marine fishes held in captivity in tidal bays. The fishery research program of the laboratory has been drastically reduced during the past year because of the lack of personnel and the necessity of supervising extensive improvements to the laboratory with funds provided by the P. W. A. and the W. P. A.

Cooperative enterprises.—Assistance and advice was given to the following agencies on matters pertaining to the marine fisheries and related industries of this general region: U. S. War Department, Corps of Engineers, concerning the construction of a larger inlet at the mouth of the New River, and its possible effect on the local oyster

fishery; cooperation with the conservation departments of North Carolina, South Carolina, Virginia, and Maryland, on matters pertaining to the propagation and regulation of oysters, crabs, and terrapin, and certain commercial fishes; a joint program with Duke University for studies of ecology of marine organisms, and particularly the parasites of marine fish and crustacea was continued; for the Union Carbon and Carbide Corporation, corrosion tests with stainless steel cable in sea water were made; for the Aluminum Company of America and the United States Navy, antifouling and corrosion tests were made of various paints used on aluminum ship plate; and improvement of the laws for encouragement of oyster farming and the protection of the natural oyster resources of this State were suggested to the Shell-fish Committee of the North Carolina State Legislature. The terrapin-propagation operations of the laboratory were made available to representatives of the Universal News Service and Fox Movietone, Inc., who prepared motion-picture films of this activity for public display. Supervision of the operation of the North Carolina Fisheries, Inc., was continued and arrangements carried out for handling fish during periods of overproduction, with the assistance of the Federal Surplus Commodities Corporation, and for the creation of a better market for clams through local processing, for a large canning concern.

Independent investigations.—The 28 independent investigators from other institutions, who were provided with laboratory facilities at various times of the year, were engaged in the following studies: Dr. W. C. George, University of North Carolina, lymphocytes of lamelli-branches; Dr. A. S. Pearse, Duke University, assisted by Helen J. Ramsey, environmental factors and faunas of sand beaches, parasites of marine animals; Dr. F. H. McCutcheon, North Carolina State College, respiration and blood of turtles; Dr. Bert Cunningham, Duke University, chemical studies of incubation of terrapin eggs; Dr. Walter E. Southwick, physiology of spermatozoa; Dr. Lawrence S. Ritchie, Womans College of the University of North Carolina, nuclear changes in protozoa; L. J. Flemister and Dr. Sarah E. Culbreth, Duke University, physiology of the swim bladder of fishes; Dr. William L. Engels and Dr. Richard A. Edwards, University of North Carolina, vertebrates of coastal islands; Dr. Wm. A. Kepner assisted by Wayland J. Hayes, Jr., University of Virginia, anatomy of Turbellaria; Dr. M. A. Stirewalt and Dr. F. F. Ferguson, University of Virginia, study of Rhabdocoels; Dr. Katharine R. Jeffers, Duke University, effect of pituitary hormones on ovaries of marine fishes; Coit M. Coker, University of North Carolina, embryology of echinoderms; Dr. and Mrs. Paul A. Meglitsch, Wright Junior College, Myxosporidia and Sarcodina of fish; Dr. Sewell H. Hopkins, Texas A. & M. College, life cycle of parasites (especially Trematoda) of marine fishes; Dr. and Mrs. George W. Wharton, Jr., Duke University, the ecology of sand beaches; Wm. E. DeTurk, Duke University, parasites of crustacea; Dr. Gordon H. Tucker, University of North Carolina, egg development of an ascidian; J. Harry Allen, University of North Carolina, distribution of marine invertebrates; Sidney Shapiro, American Museum of Natural History, differential growth in scombriform fish; A. B. Hardcastle and Margaret Hardcastle, Duke University, life history and parasites of menhaden.

Propagation of the diamond-back terrapin.—The total production of young terrapin hatched and reared at Beaufort, N. C., amounted

to 14,140 for the present season, and is the highest record obtained thus far in the culture of this species. The greatest previous annual production was obtained in 1938, when 13,600 were hatched in the 7 concrete breeding pens surrounding the station. This is the world's largest terrapin farm, or hatchery, and has supplied approximately 144,000 of these salt-marsh turtles for restocking coastal areas since the artificial propagation of this species was undertaken in 1909. The 1939 brood has been placed in special hibernating boxes in the large rearing house and will be distributed next spring throughout the South Atlantic region in cooperation with the various State conservation agencies.

The increased yield from these operations in the past 2 years can be attributed to experimental improvements made under the direction of Dr. Prytherch and Capt. Charles Hatsel, with respect to reducing the concentration of brood stock in certain of the breeding pens. For example, in one pen where the adult terrapin were provided with twice as much space in 1938 and 1939 as in 1937, the production of young increased from an average of 8 per female in 1937 to 10 and $11\frac{1}{2}$ per female, respectively, in 1938 and 1939. Also, in the two new large pens, which provide ample room for the brood stock, the total production of young for each group of 500 adults—consisting of 400 females and 100 males—increased from 1,200 in 1937 to 3,360 in 1938, and 3,490 in 1939. In all of the experimental pens, in which crowding has been reduced, the average production of eggs per female terrapin showed increases ranging from 20 to nearly 200 percent in the past 2 years, with a fertility of over 95 percent. The increased production of young diamond-backs in 1939 is particularly significant and encouraging because seasonal conditions in that year were apparently less favorable for breeding than usual, as the 2 "control," or unimproved pens showed a decrease of over 20 percent in output in comparison with the average result obtained over a previous 5-year period. Also, during 1939, the brood terrapin were frequently disturbed, and their egg-laying activities were interfered with to a considerable extent while a P. W. A. project was in progress. This project made extensive improvements by elevating the concrete walls of all the pens, providing new tidal gates, and by enlarging the area of the egg beds.

The total brood stock at present consists of 570 males and 2,025 females, most of which have been in captivity for a period ranging from 10 to 25 years. In 1937 one of the pens was stocked with 320 wild terrapin, at a ratio of 70 males to 250 females, in order to determine the length of time required to reach satisfactory egg production. The output of young terrapin from this group increased from 460 in 1938 to 790 in 1939. Considerable interest in the terrapin-culture method developed at the Beaufort Station has been shown by the fisheries commissioners of Maryland and Virginia, who plan to inaugurate similar operations in their States within the next 2 years. In the spring, the output of the Beaufort Station usually is distributed in the coastal region from Maryland to Florida, after the young terrapin have been protected and fed for the first 9 months of their lives. This work has not only provided a large supply of young terrapin for restocking depleted salt-marsh areas, but has saved thousands from destruction by natural enemies such as rats, gulls, crabs,

and other predators, by protecting them during the time of egg incubation and the hibernating period during the first winter, when they are in hiding along the shore just above high-water level.

Experiments in marine fish farming.—Over 15,000 salt-water fish, consisting chiefly of striped mullet, did not migrate as usual this winter, but instead were forcibly detained in experimental tidal ponds constructed at the biological laboratory at Beaufort, N. C. Two years ago these ponds were constructed in cooperation with the W. P. A. and the North Carolina Conservation Department in order to determine the possibility of utilizing salt-marsh ponds and small coastal bays for rearing and live storage of fish, and for oyster culture. The experimental operations, conducted here since 1938 under the supervision of Dr. Prytherch, have demonstrated that by improvement of tidal areas through the construction of dikes, sluice gates, or other devices, it is possible to grow mullet, spotted trout, flounders, channel bass, sheepshead, croakers, and several other common species in captivity, or store them in a live, healthy condition for many months until there is a favorable market. The ponds also proved satisfactory for protected natural spawning and rearing of the mullet, which is the most important food fish taken in the South Atlantic and Gulf States. The production of the striped mullet in this region amounts to approximately 40 million pounds annually, with a return to the fishermen of nearly $1\frac{1}{2}$ million dollars. During periods when the markets are glutted with mullet the coastal ponds would make possible the temporary live storage of a considerable quantity, thus maintaining better prices for the fishermen and making available a supply of fresh fish at any season of the year.

In the fall of 1938 the experimental ponds were stocked with over 3,000 fish ranging in size from roe mullet, weighing over 5 pounds, to small immature fish having a length of 6 to 8 inches, which were approximately 1 year old. The fish were captured with nets during their fall migration and were transported to the pond by means of a perforated boat, or live car having a capacity of approximately 400 pounds. Most of the mullet were placed in the larger tidal pond, which has an area of approximately $2\frac{1}{2}$ acres at low water, and a maximum depth of 15 feet, and receives an exchange of over 5 million gallons of water daily through the two tidal gates. Several hundred immature mullet were placed in the smaller observation pond, and in large concrete pools at the laboratory, where they have been studied with respect to feeding habits and ability to survive low water temperatures during the past 2 winters. The adult mullet spawned in captivity during November 1938, and stocked the pond with thousands of young which, by the latter part of December, had attained a length ranging from $\frac{1}{2}$ to $\frac{3}{4}$ inch. Though no attempt was made to hold these young fish in the pond by the use of fine-meshed screen on the tidal gates, there was, nevertheless, a considerable number that remained in the ponds and grew to an average length of over 6 inches during the first year. Less than 1 percent of the fish died from injuries sustained during collection and transportation, or during the subsequent period of 15 months that they were held in captivity.

Operations during 1939 were conducted on a small commercial scale, using a special barge equipped with a built-in live box and

water-circulating system, and capable of transporting 3,000 to 5,000 fish ranging in weight from $\frac{1}{2}$ to 1 pound each. The catches of mullet were obtained from regular fishing crews who were able to transfer them directly into the barge without exposing the fish to air for more than a few seconds. On arrival at the storage pond the fish were released from the barge into a receiving lock, from which they swam into the pond with the flood tide. A total of over 12,000 mullet were placed in captivity by this procedure, along with a few hundred specimens of croakers, spot, pigfish, white perch, and other species.

No additional roe mullet were placed in the ponds in 1939, because it was important to first determine whether those held in captivity since the previous year had continued to grow and develop spawn to the extent that they would under natural conditions. A number of the largest fish were caught in October and November 1939 and examined as to quantity of spawn, condition of the flesh, and number of growth zones on the scales. These specimens, ranging in weight from $2\frac{1}{2}$ to 5 pounds, were found to contain ripe roe which weighed from $6\frac{1}{2}$ to 12 ounces, according to the size of the fish. Experienced local fishermen expressed the opinion that these mullet were in as fine condition, and as fully developed with roe, as those being captured at that time in the commercial fisheries. Studies of the scales showed that the growth of the impounded fish had been considerable since their last winter spawning period, and equivalent to that found in free individuals which had spent the previous summer in these waters. The general results indicate, therefore, that ponds of this type can be used not only for growing mullet without artificial feeding, but also as automatic marine hatcheries having an approximate output of 500 million fry per acre. The tidal flats and shallow areas in the ponds were also used successfully for oyster culture, which, at the same time, improved conditions for production of the natural food of the mullet.

Improvements to the Beaufort Laboratory.—Extensive repairs and improvements were made to the buildings, equipment, and grounds of the laboratory with funds provided by the P. W. A. and the W. P. A. The main laboratory and dormitory rooms were refinished inside with suitable wallboard, some new flooring was laid, and modern plumbing fixtures and improved electrical conduits and outlets for the experimental tanks and other special equipment were installed. The salt-water system was greatly improved by the installation of new pipe lines with continuous flow and valve arrangements that permit complete flushing and removal of sediment without interference with experiments. A new supply of fresh water is obtained from a 3-inch artesian well drilled on the island, which has an overflow of 25 gallons per minute that is distributed to the 8 terrapin pens. In the various laboratory rooms 10 new experimental tanks have been constructed and provided with flood lights and outlets for salt and fresh water, electricity, and compressed air.

The terrapin-rearing house was completely remodeled, and 12-foot additions were placed on each side; one for a small aquarium and the other for the storage of lumber, equipment, and supplies. In the aquarium a small exhibit of marine fish, turtles, crustaceans, and other aquatic animals has been made possible by the installation of 2 large

circular tanks, 4 shallow rectangular tanks, and 12 glass aquaria. Five large outdoor tanks of reinforced concrete have been constructed for displaying large specimens. Considerable repairs were made to the sea wall, the terrapin pound, walks, driveways, and building foundations. A small pier and a 20,000-gallon storage tank for salt water were erected adjacent to the terrapin-rearing house in order to improve facilities for the feeding and care of the young terrapin.

With the assistance of the National Youth Administration it has been possible to improve considerably the exhibits of fish, crustacea, shellfish, etc., in the laboratory museum. An inexpensive method has been perfected for making accurate lifelike reproductions of marine fishes, from materials which appear satisfactory for permanent use in this climate. Casts of the following specimens have been added to the museum collection: A 75-pound ocean sunfish; 250-pound spotted whiplay; 7-foot sailfish; 100-pound stingray; 6-foot sandshark; hammerhead shark; tarpon; amberjack; dolphin fish; sheepshead; angel shark; sturgeon, tripletail; Spanish mackerel; long-finned albacore; black drum; and many other common species of smaller size. This project is being continued in cooperation with a division of the W. P. W. that is preparing visual aids to education for use in schools, libraries, etc. Small exhibits are being developed showing interesting phases of fish life, commercial methods of capture, and the nutritional importance of marine fish and shellfish.

APPROPRIATIONS

Numerous changes in the sources of funds for the Division of Scientific Inquiry brought about what appears to be a diminished amount available for fishery investigations during the fiscal year 1940. The appropriations for specific activities during the fiscal year 1939 included funds for travel and vessel operation made available from the deficiency appropriation of \$76,000 during that year for the Bristol Bay salmon investigations. The appropriations for that work during the fiscal year 1940 were placed under the proper headings. The grand total of the appropriations for the fiscal year 1940 exceeded the 1939 grand total by \$20,430. When proper adjustments are made for non-recurring items in both fiscal years, an actual increase of \$19,000 was realized in 1940.

The actual appropriation for the construction of fish screens and ladders in 1940 was equivalent to one-half of the 1939 sum, and an additional total of \$4,380 was supplied from other sources in order to maintain the program. Provision was made in the 1940 appropriations for the construction of a small permanent laboratory at Little Port Walter, in Southeastern Alaska.

Additional funds were received for the fiscal year 1940 from the Works Progress Administration for the improvement of the biological station at Pensacola, Fla. The National Industrial Recovery allotment provided \$25,000 for the completion of a new biological laboratory at Milford, Conn., and \$125,000 for the reconditioning and alteration of a commercial trawler which will become the new fishery research vessel, *Albatross III*.

Approximately one-half of all available funds of the 1939 and 1940 appropriations were spent during the calendar year 1939. A state-

ment of the appropriations, allotments, and special funds available for the use of the Division is given in the following table:

Project	1939	1940
Regular appropriations:		
Commercial fishery investigations.....	\$222, 300	\$186, 115
Oyster-cultural investigations.....	50, 620	54, 000
Aquicultural investigations.....	46, 880	55, 950
Conserving fish by screens and ladders.....	20, 000	14, 380
Water quality studies.....	11, 100	10, 600
Washington laboratory and administration.....	7, 100	4, 655
Construction of Southeastern Alaska laboratory.....		7, 500
Administrative reserve for savings.....		6, 300
Total.....	358, 000	339, 500
Allotment for traveling expenses.....	31, 620	38, 200
Allotment for maintenance and operation of vessels.....	30, 450	62, 800
Total.....	62, 070	101, 000
Grand total.....	420, 070	440, 500
Special funds:		
State of Virginia oyster fund.....	5, 000	-----
State of Maine lobster fund.....	2, 500	-----
Public Works Administration projects.....	281, 050	-----
Works Progress Administration projects.....	127, 645	19, 000
National Industrial Recovery projects.....		150, 000
Total.....	416, 195	169, 000



